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# 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
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DIPARTIMENTO DI SCIENZE AGRARIE - UNIVERSITÀ DI BOLOGNA

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***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*

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# *CROPPING SYSTEMS FOR CULTIVATION OF VERY EARLY MATURITY MAIZE HYBRIDS*
## *PERCORSI AGRONOMICI PER LA COLTIVAZIONE DEI MAIS PRECOCISSIMI*

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**Abstract**
A new generation of very early maturity hybrids (FAO class 200) was recently introduced in Italy. These new maize hybrids are characterized by several crop features that could radically modify their role in the cropping system due to a reinforced early vigor, a greater plant development and size, a higher grain production, a good grain quality. This research analyzes for early and late planting time different crop density by the application of two inter-row on productive and quality parameters and compare this results with a full season maturing hybrid cropped under more convention practice. As main crop, the very early hybrids were harvested 1 month before the full season maturing ones. The results pointed out a positive increasing of yield up to 10.5 plants $m^{-2}$ for the wider inter-row spacing, and until 12.0 or 10.5 plants $m^{-2}$ for the narrow as main or inter-crop respectively. Despite yield potentiality is clearly raised reaching 14 t $ha^{-1}$, full cycle hybrid resulted in an higher yield up to 26%; this productive deficit does not eliminate completely the yield gap involving the very early hybrids. Thus, very early maize hybrids remain profitable for grain production as main crop in supply food chain agreements that valorize their higher sanitary and technological quality or when environmental constrains are awaited.

**Keywords:** maturity class, sowing time, plant population, yield, grain quality.
**Parole chiave:** precocità di maturazione; epoca di semina; densità colturale, produttività, qualità.

**Introduction**
Recently in the Italian growing maize area (Po plain) a new generation of very early maturity hybrids (FAO Class 200, < 85 days from plant emergence to physiological maturity) were introduced. Traditionally hybrids classified as ultra-early maturity (FAO 100), very early maturity (FAO 200) and early maturity (FAO 300) have been utilized mainly for delayed planting after a winter cereal as barley or wheat in the irrigated areas. Nevertheless, under dry conditions, as the main crop, early maturing hybrids were also cultivated in the more stressed areas for spring planting time. Until the last years, as a consequence of the short crop cycle and of the more severe constrains of the crop practice, the expected grain yield of the early maturing hybrids were generally much lower compared to the medium (FAO 4-500) or late (FAO 6-700) maturing hybrids. More recently a generation of new very early hybrids, were introduced: compared to the previous generation, these genotypes are characterized by several crop features that could radically modify their role in the crop system. In particular these hybrids show a reinforced early vigor, a greater plant development and size, a higher grain production, a good grain quality (semi-vitreous kernel, for food purpose) and a lower attitude to mycotoxin severe contamination.
These features stress to explore the opportunity to introduce these hybrids not only in the more stressed areas or for delayed planting times, but also in more favorable conditions, considering the prospect to reduce variable cost of irrigation and nitrogen fertilization, protection (insecticide application) and post-harvest drying (Lindsey et al., 2015). However, also considering the potential economic advantages linked to the reduction of the variable cost, the yield gap compared to full season hybrids is still the limiting factor for the diffusion of very early maturing hybrids. Nevertheless, the favorable plant architecture and the kernel ripeness collocation in the middle of the summer suggest the possibility of increasing plant density in order to enhance the radiation intercepted by the canopy and grain yield (Li et al., 2015; Testa et al., 2016).
The aim of this research has been to analyze different crop density by the application of two inter-row spacings on different productive and quality parameters and to compare these results with a more traditional medium or late maturing hybrid cropped under more standard practice.

**Materials and Methods**
Field trials were conducted in the 2015 and 2016 growing seasons at Chivasso and Carignano (TO), in the North West of Italy, characterized by a sandy-loam soil and medium content of organic matter.
The experiment was carried out on very early maturity hybrids (FAO maturity group 200, 85 days of relative maturity): KWS Ronaldinio (2015 experiment) and KWS Kasimens (2016 esperiment).
In each year and location the compared treatments were a factorial combination of:
- 2 cropping systems that differ for planting time: maize as main crop, planted in early spring; maize as inter-crop, planted after barley harvest;


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- 2 inter-row spacings:- 0.75 m wide, standard inter-row spacing, representing the reference spacing for the maize crop system;- 0.5 m wide, narrow inter-row spacing
- 4 planting densities:- 9, 10.5, 12 and 13.5 plants $m^{-2}$.

The treatments were assigned to experimental plots using a completely randomized block design, with four replications. The plot size was 10 x 3 m, and each plot consisted of 8 rows. The plot alleys, orthogonal to the maize rows, were one meter wide. In each location and year the very early maturity hybrid was compared also to a reference condition, carried out in farm field cultivated with a full season maize hybrids (FAO maturity group 500, 125 days of relative maturity) with a plant density of 8 plants $m^{-2}$.

Conventional agronomic techniques were adopted for the field experiments in both growing seasons. Briefly, the previous crop was maize, and mechanical sowing was carried out after an autumn ploughing (30 cm) and disk harrowing to prepare a suitable seedbed. All the plots received the same amount of nutrients: 250, 100 and 100 kg $ha^{-1}$ of N, $P_2O_5$ and $K_2O$, respectively. Irrigation was carried out by means of the furrow surface method in order to prevent drought stress until the end of the dough stage (GS 87). All the plots were sprayed at GS 75 with pyrethroid lambda-cyhalothrin insecticide (Karate® Zeon, Syngenta Crop Protection S.p.A., Milan, Italy) at 0.019 kg AI $ha^{-1}$ using a self-propelled ground sprayer (Eurofalcon E140®, Finotto, Italy). The treatment was performed, according to the growth stage, in the middle of July for the early sowing date and in the first decade of August for the late sowing date, in order to minimize the ear injuries caused by the activity of the European Corn Borer (ECB – Ostrinia nubilalis, Hübner). The sowing, harvest and the flowering dates for each growing season and site are reported in Table 1.

The following morphological features were recorded: plant height, stalk area at the first internode, leaf area index (LAI). Ears were collected by hand from 6 $m^2$ (2 rows x 4 m) of each plot at harvest maturity in order to quantify the grain yield (adjusted to a 14% moisture content). The ears were shelled using an electric sheller, and kernels from each plot were mixed thoroughly to obtain a random distribution. The normal distribution and homogeneity of variances were verified by performing the Kolmogorov–Smirnov normality and Levene test. The analysis of variance (ANOVA) was run, using a completely randomized split plot design in order to analyze the effect of combination of plant density and the inter-row spacing separately for the considered cropping system (main crop, inter-crop), by considering the experiment (combination of site and year) as a random factor. When necessary, post-hoc multiple comparison tests were performed, according to the Ryan-Einot-Gabriel-Welsh F (REGWF) test.

*Tab. 1: Main information of experimental trials*
*Tab. 1:Principali informazioni agronomiche delle prove sperimentali*

| Year | Site | Maturity class (FAO) | Cropping system | Dates | | |
|---|---|---|---|---|---|---|
| | | | | planting | flowering | harvest |
| 2015 | Chivasso | 500 | Main crop | 03 April 2015 | 30 June 2015 | 07 September 2015 |
| | | 200 | Main crop | 03 April 2015 | 16 June 2015 | 11 August 2015 |
| | | 200 | Intercrop | 19 June 2015 | 01 August 2015 | 14 October 2015 |
| | Carignano | 500 | Main crop | 02 April 2015 | 01 July 2015 | 10 September 2015 |
| | | 200 | Main crop | 02 April 2015 | 19 June 2015 | 13 August 2015 |
| | | 200 | Intercrop | 17 June 2015 | 03 August 2015 | 26 October 2015 |
| 2016 | Chivasso | 500 | Main crop | 07 April 2016 | 06 July 2016 | 14 September 2016 |
| | | 200 | Main crop | 07 April 2016 | 24 June 2016 | 31 August 2016 |
| | | 200 | Intercrop | 13 June 2016 | 04 August 2017 | 19 October 2016 |
| | Carignano | 500 | Main crop | 31 March 2016 | 07 July 2016 | 22 September 2016 |
| | | 200 | Main crop | 31 March 2016 | 22 June 2016 | 24 August 2016 |
| | | 200 | Intercrop | 15 June 2016 | 05 August 2016 | 18 October 2016 |

**Results and Discussion**

In both growing seasons planting took place within the first decade of April as main crop and the middle of June as intercrop, according to a possible sowing following a barley harvest.

The two growing seasons differed in terms of rainfall and temperature, mainly during summer period. Lower temperature were recorded in 2016 resulting in a slowdown of ripening and a delayed of the harvest of the very early maturing hybrids, while for the full maturing hybrids the harvest time was rather similar (Table 1). As main crop, the very early hybrid has anticipated the harvest of about 1 month, compared to the full season one,

The interactions among treatments (combination of plant density and inter-row spacing) x location and treatments x year were never significant: thus the data shows the average of the 2 locations and the 2 years.

The effect of cropping system, planting density and inter-row on the plant morphological traits is summarized in table 2. Plant height was never influenced by the planting techniques, while the stalk area for the main crop stand was negatively influenced by the enhancement of the crop density and by the wider inter-row (75 cm) compared to the narrow one (50 cm). The plant leaf area was significantly reduced by the increase of the crop density, in both the cropping systems; despite this reduction, the canopy LAI was linearly increased by the crop density from 3.8 to 5.2 considering the extreme condition of 9.0 and 13.5 plants $m^{-2}$.

*Tab. 2: Effect of plant density and inter-row spacing on morphological traits of very early maturity maize hybrid under different cropping system.*

*Tab. 2: Effetto della densità colturale e del sesto di impianto sui parametri morfologici di ibridi di mais precocissimi nell'ambito di sistemi colturali con differente epoca di semina.*

| Cropping System | Inter-row | Plant density (plant $m^{-2}$) | Plant height (cm) | Stalk area ($cm^2$) | Leaf area ($cm^2$ $plant^{-1}$) | LAI |
|---|---|---|---|---|---|---|
| Main crop | 75 cm | 9 | 233 a | 3.0 bc | 4138 a | 3.7 E |
| | | 10.5 | 233 a | 2.7 d | 3993 ab | 4.2 D |
| | | 12 | 232 a | 2.5 e | 3839 b | 4.6 C |
| | | 13.5 | 234 a | 2.4 e | 3816 b | 5.2 A |
| | 50 cm | 9 | 230 a | 3.3 a | 4185 a | 3.8 E |
| | | 10.5 | 232 a | 3.1 b | 4113 a | 4.3 D |
| | | 12 | 235 a | 2.8 cd | 4088 a | 4.9 B |
| | | 13.5 | 234 a | 2.7 de | 3823 b | 5.1 A |
| Intercrop | 75 cm | 9 | 218 a | 2.8 ab | 3888 ab | 3.5 D |
| | | 10.5 | 220 a | 2.6 bcd | 3752 abcd | 3.9 C |
| | | 12 | 223 a | 2.5 cd | 3616 bcd | 4.3 B |
| | | 13.5 | 221 a | 2.4 d | 3520 d | 4.8 A |
| | 50 cm | 9 | 222 a | 2.9 a | 3943 a | 3.5 D |
| | | 10.5 | 227 a | 2.9 a | 3809 abc | 4.0 C |
| | | 12 | 221 a | 2.7 bc | 3692 abcd | 4.4 B |
| | | 13.5 | 223 a | 2.4 d | 3566 cd | 4.8 A |

Within each cropping system, means followed by different letters are significantly different ($p<0.05$)

Enhancing crop population increased ear density for both the inter-row spacings, although under the highest densities an increased number of barren plants (plant without fertile ears) was recorded (Table 3). Although the negative effect of crop population on the plant fertility, the kernel density (kernels $m^{-2}$) was always linearly increased by the enhancement of the


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crop density, although in intercrop condition the thousand kernel weight (TKW) was negatively influenced by the more dense stands (Table 3).

*Tab. 3: Effect of plant density and inter-row spacing on yield component of very early maturity maize hybrid under different cropping system.*
*Tab. 3: Effetto della densità colturale e del sesto di impianto sui componenti della resa di ibridi di mais precocissimi nell'ambito di sistemi colturali con differente epoca di semina.*

| **Cropping System** | **Inter-row** | **Plant density** ($n\ m^{-2}$) | **Ear density** ($n\ m^{-2}$) | **Barren plant** (%) | **Kernel** ($n°\ m^{-2}$) | **TKW** (g) |
|---|---|---|---|---|---|---|
| Main crop | 75 cm | 9 | 9.0 d | 1.3 c | 3465 d | 332 a |
| | | 10.5 | 10.6 c | 1.6 c | 3919 bcd | 332 a |
| | | 12 | 11.4 b | 3.6 bc | 4078 ab | 325 a |
| | | 13.5 | 11.8 b | 9.3 a | 4050 ab | 323 a |
| | 50 cm | 9 | 9.1 d | 1.7 c | 3553 d | 336 a |
| | | 10.5 | 10.6 c | 1.4 c | 4003 abc | 336 a |
| | | 12 | 12.0 b | 1.6 c | 4297 ab | 326 a |
| | | 13.5 | 12.5 a | 6.5 ab | 4461 a | 325 a |
| Intercrop | 75 cm | 9 | 8.8 d | 2.3 d | 2882 d | 316 abc |
| | | 10.5 | 10.0 c | 7.0 bc | 3033 cd | 309 bcd |
| | | 12 | 10.5 c | 9.9 ab | 3027 cd | 302 cd |
| | | 13.5 | 11.1 b | 11.7 a | 3208 bc | 294 d |
| | 50 cm | 9 | 8.9 d | 2.6 d | 2947 cd | 328 a |
| | | 10.5 | 10.1 c | 2.6 d | 3232 bc | 320 ab |
| | | 12 | 11.2 b | 5.6 cd | 3468 ab | 298 d |
| | | 13.5 | 12.2 a | 6.8 bc | 3605 a | 297 d |

Within each cropping system, means followed by different letters are significantly different ($p<0.05$)

Cropping system, planting density and inter-row spacing have influenced grain yield and moisture (Table 4). On average, the cultivation of very early maturity hybrid as main crop has increased yield by the 48% compared to the intercrop. On the other hand, the narrow inter-row (0.50 cm of inter-row) has positively influenced the production, showing a 7% grain yield for both the cropping systems. However the influence of the crop density was different within the applied inter-row spacing: significant increasing of yield was recorded until 10.5 plants $m^{-2}$ for the wider inter-row spacing (75 cm) and until 12.0 plants $m^{-2}$ for the narrow one (50 cm). The yield advantage of narrow inter-row spacing is mainly linked to the lower incidence of barren plants achievable at high plant density with the application of this pattern compared to the conventional one. Grain moisture was only clearly influenced by crop density in the late planting time (maize as intercrop).
Full cycle hybrid that was grown as comparison for the main cropping system has yielded 16.1 t $ha^{-1}$ with an increase of 26% for the best crop density for the wider inter-row and of 15% with the narrow inter-row.

**Conclusions**
With the introduction of a new generation of very early maturity hybrids (FAO Class 200) yield potentiality is clearly raised under irrigated conditions reaching 14 t $ha^{-1}$. These productions were obtained only when seeding took place in the beginning of the spring adopting a very high crop density with a narrow inter-row spacing to reduce canopy self-shading. In this condition anthesis occurs in the second decade of June corresponding to the most intensive radiation and the plant photosynthesis is at the highest rate. Very early hybrids under late seeding conditions as intercrop, has proved to effectively reduce yield compared to spring sowing; moreover, the more limiting radiation of August at anthesis has stressed the evidence to sustain lower plant density and then to be less influenced by a narrow inter-row.
The clear enhance of yield under a more intensive plant population, reduce but does not eliminate completely the competitive gap in respect to a full season maturing hybrid. Thus, very early maize hybrids will be profitable for grain production in as main crop in supply food chain agreements that could valorize the lower contamination of mycotoxins and the high hardness of kernel or in all the conditions when nutritional factors are limiting or other environmental constrains are awaited.


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*Tab. 4: Effect of plant density and inter-row spacing on grain yield and moisture of very early maturity maize hybrid (FAO 200) under different cropping system, in comparison to a full season hybrid (FAO 500).*
*Tab. 4: Effetto della densità colturale e del sesto di impianto sulla produzione e l'umidità della granella di ibridi di mais precocissimi (FAO 200) nell'ambito di sistemi colturali con differente epoca di semina, in confronto a un ibrido di ciclo pieno (FAO 500).*

| **Cropping System** | **Hybrid class** | **Inter-row** | **Plant density** (plant $m^{-2}$) | **Yield** (t $ha^{-1}$) | | **Grain moisture** (%) | |
|---|---|---|---|---|---|---|---|
| Main crop | 500 | 75 cm | 8.0 | 16.1 | | 24.9 | |
| Main crop | 200 | 75 cm | 9.0 | 11.8 | e | 24.8 | a |
| | | | 10.5 | 12.9 | cd | 25.5 | a |
| | | | 12.0 | 12.7 | cd | 25.6 | a |
| | | | 13.5 | 12.4 | cde | 25.7 | a |
| | | 50 cm | 9.0 | 12.3 | de | 25.0 | a |
| | | | 10.5 | 13.1 | bc | 25.6 | a |
| | | | 12.0 | 14.0 | a | 25.7 | a |
| | | | 13.5 | 13.6 | ab | 25.8 | a |
| Intercrop | 200 | 75 cm | 9.0 | 8.8 | b | 27.1 | b |
| | | | 10.5 | 8.6 | bcd | 27.6 | ab |
| | | | 12 | 8.1 | cd | 28.6 | ab |
| | | | 13.5 | 8.0 | cd | 27.7 | ab |
| | | 50 cm | 9.0 | 8.8 | bc | 28.1 | ab |
| | | | 10.5 | 9.7 | a | 28.3 | ab |
| | | | 12 | 8.9 | bc | 28.3 | ab |
| | | | 13.5 | 8.5 | bcd | 28.8 | a |

Within each cropping system, means followed by different letters are significantly different ($p<0.05$)

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