Effect of the sowing ratios on the yield and quality of seed from maize genotypes

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ABSTRACT

Objective: To identify optimal sowing ratios, validation of production technology and seed quality in maize hybrids.

Design/methodology/approach: Sowing ratios of 4:2 and 6:2 were studied to observe their effect on the genotypes, as well as their quality and response in seed production; this was done by evaluating the following variables: days to male and female flowering, plant and ear height, percentage of ear and seed in cobs, commercial seed yield, thousand seed weight, number of seeds per kilogram, standard germination and hectoliter weight of the seed. An analysis of variance was carried out using a completely randomized design with factorial arrangement and four replications, the experimental unit being furrows of 20 linear meters.

Results: Significant differences were detected in the hybrids with respect to the variables and sowing ratios, which specifically influences the weight, size and number of seeds; the hybrid H-386A had the best response to the environment and ratios, exceeding the rest of the hybrids evaluated by 72.92%.

Limitations on study/implications: The interaction of genotype and environment are factors that limit seed production; however, performing evaluations in different environments allows finding stable hybrids with high yields.

Findings/conclusions: The generation of knowledge allows us to make decisions regarding crop establishment and quality in seed production lots, being a recommended environment in CIRPAC's area of influence.

Keywords: *Zea mays* L., INIFAP hybrids, production, flower synchronization.

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INTRODUCTION

The National Institute for Forest, Agriculture and Livestock Research (*Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias*, INIFAP), generates and liberates hybrids for different agroecological zones of the country, and the acceptance of these hybrids by

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farmers is possible because parents are supplied in category registered to different national companies devoted to seed production. In addition to this, it is necessary to develop technologies to identify the environments that are favorable and the seed quality (physical, physiological, sanitary and genetic) for sowing. Through the Centro Altos Experimental Field from Jalisco, which depends on the *Centro de Investigación Regional Pacífico Centro* (CIRPAC), activities in genetic improvement of maize are developed, to obtain new hybrids of white and yellow grain, which can be used in the subtropical zone of the Central Pacific of Mexico. The adoption of these new materials will depend on the yield potential and seed quality from the parent lines, as well as the yield potential of the grain from hybrids at the commercial level.

In the generation of improved varieties and the production of maize seed, agricultural research and teaching institutions have contributed to the offer of quality seed (Larque *et al.*, 2013; Domínguez and Donnet, 2014). Likewise, García *et al.* (2018) mention that the use of quality seeds constitutes one of the most profitable investments in the economy of every farmer, and widely justifies the research in adequate techniques to produce the maximum amount of high quality hybrid maize (*Zea mays* L.) seed. The seed yield and quality can be increased with changes in agricultural practices, such as the sowing pattern, referring to the number of furrows with female plants in relation to the furrows with male plants.

During the production process of the seed, its quality is controlled; however, there is scarce information about the technology of seed production of registered and certified categories. In hybrids, the potential yield and seed quality of parents (lines and simple crosses) have been evaluated, and seed production sites have been identified (Virgen *et al.*, 2010; Arellano *et al.*, 2011).

It has been found that the maize seed yield of the compact sowing pattern is equal (García *et al.*, 2014) or superior (Beck, 2004) to the conventional system; however, there is no information about its effect on the physical and physiological quality of the seeds obtained, which is why it is necessary to evaluate the quantity and the quality of the hybrid seeds produced based on attributes that favor the establishment and development of the plants in the field.

However, it is still essential to understand the behavior of the parents, lines and simple crosses, in production localities, and their interaction with the environment to obtain a quality hybrid seed (Virgen *et al.*, 2016). Therefore, in order to determine whether the materials fulfill the requirements mentioned before, this research study was established in one of the main producing zones of certified maize seed and influence area of national companies linked to INIFAP-CIRPAC, with the objective of identifying the optimal sowing ratios, validating the production technology and seed quality of the hybrids H-384A, H-385A and H-386A.

MATERIALS AND METHODS

The research study presented here was conducted during the Fall-Winter 2012/2013 cycle, in Coquimatlan, Colima. This is an important zone in the production of maize seed, with regards to the area of influence (Table 1), whose characteristics are presented next.

Table 1. Location of the agroclimate conditions of the locality of study.

Locality	Municipality and State	Altitude msnm	Temperature mean °C	Weather	Location	
					Latitude N	Longitude W
Coquimatlán	Coquimatlán, Colima.	400	26.1	Warm Subhumid	19° 11' 52"	103° 48' 41"

In this study, three hybrids generated by INIFAP in the Pacific-Center region were evaluated. In this locality, seed production lots of the yellow grain hybrids H-384A (G1), H-385A (G2), H-386A (G3) were established, whose parents are: simple cross of lines B-4A×B-6A (female), B-7A (male), and B-4A×B-6A (female), B-7A×B-8A (male) and B-3A×B-6A (female), B-9A (male), respectively. The ratios of females and males were: 4:2 (R1) and 6:2 (R2) (Table 2).

Establishment and management. For the study of the three hybrids, they were established with a female:male furrow ratio of 4:2 (R1) and 6:2 (R2); in furrows by 0.8 meters of width, with a depth of 5 cm. Sowing was done simultaneously for G1 and G2, while for the hybrid H-386A, the male was established first and five days later the female, with 7 to 8 seeds being deposited per linear meter.

The response variables considered were: days until male flowering (MF), days until female flowering (FF), plant height (PH), ear height (EH), percentage of ear in female cobs (PE), percentage of seed in female ears (SFE), commercial seed yield (CSY), thousand seed weight (TSW), number of seeds per kilogram (S/kg), standard germination (G), and hectoliter weight of the seed (HW), which were taken based on the procedure described by ISTA (2004).

Statistical analysis. The information obtained from each of the variables studied in this study was analyzed with the SAS 9.4 software. A completely randomized design was used, and the treatments had a factorial arrangement with four repetitions, where each experimental unit consisted in furrows of 20 linear meters. Analysis of variance was carried out, and in the response variables where a significant statistical difference was observed a means comparison was carried out (Tukey P≤0.05) (SAS Institute, 2002).

Table 2. Relation of hybrids, parents, Split and sowing rate or female:male (F:M) furrow proportion.

Experimental hybrid	Parent		Split (days)	Row ratio Female:Male
H-384A (G1)	B-4A×B-6A	(Female)	Simultaneous	4:2 (P1) y 6:2 (P2)
	B-7A	(Male)		
H-385A (G2) H-386A (G3)	B-4A×B-6A	(Female)	Simultaneous more 5 days AT	4:2 (P1) y 6:2 (P2) 4:2 (P1) y 6:2 (P2)
	B-7A×B-8A	(Male)		
	B-3A×B-6A	(Female)		
	B-9A	(Male)		

(G1) genotype one, (G2) genotype two, (G3) genotype three, (R1) proportion one, (R2) proportion two and AT; on time, that is, the first sowing establishment when there is Split in days between female and male.

RESULTS AND DISCUSSION

In this study, the genotypes and proportions were mainly analyzed with regards to the variables studied. Tukey's means comparison test (Table 3) established differences in the variables studied, regarding the variation factors, although there are numerical differences between them. Concerning the effect in the yield (t ha^{-1}), genotype three (G3) exceeds G2 and G1, in 36.01 and 50.99 %, respectively, which compared to other variables that can be moved by several factors corresponding to the crop's management (fertilization, irrigation, etc.) and their statistical and numerical difference indicates specific decision making for the locality and the genotypes in study.

For the physical characteristics of the grain, it was observed (Table 3) that the 1000 seed weight TSW (g) for genotype three (G3) was 357.38 g, exceeding G1 and G2, obtaining the highest weight with ratio two (R2); in addition, in this locality the number of seeds per kilogram resulted in the G3 presenting the lowest number of seeds, which means that the seeds of this material are larger than the rest of the genotypes in study, and this did not affect an increase in female:male ratio to 6:2, that is, six furrows of female by two of male. In the analysis of variance, significant statistical differences were observed due to the ratio of male *vs*. female plants, the means test ($P \leq 0.05$) only showed difference in plant height and ear height, but did not present statistical difference in male and female flowering. Regarding the ratios, the contrary case in the genotypes where more precociousness is seen is G3, followed by G2, and the slowest in flowering being G1. This could probably be attributed to the genetic characteristics of the parents, standing out or presenting this in parent three (G3). There are key factors in the success of seed production, among them the ratio of female furrows to male furrows. In this regard, MacRobert *et al.* (2014) point out that the most common ratios are: 2:1, 3:1 and 6:2. According to this, we could reconcile

Table 3. Means comparison of the variables evaluated for genotypes and sowing ratios.

Variables	Genotypes				Proportions		
	G1	G2	G3	DMS	P1	P2	DMS
FM (Days)	69.50 a	69.00 b	63.50 c	0.00	67.33 aa	67.33 a	0.00
FF (Days)	70.00 a	69.00 b	68.00 c	0.00	69.00 aa	69.00 a	0.00
AP (m)	2.40 abb	2.28 b	2.42 aa	0.11	2.32 b	2.41 a	0.07
AM (m)	1.25 c	1.43 b	1.64 a	0.10	1.50 a	1.38 b	0.07
OLO (%)	26.03 a	18.30 b	21.08 bb	4.51	22.65 aa	20.96 a	3.03
SEM (%)	73.96 b	81.69 aa	78.91 a	4.51	77.34 a	79.03 aa	3.03
PH(Kg hL^{-1})	78.27 abb	81.20 aa	76.21 b	2.98	78.10 a	79.02 aa	2.00
PMS (g)	300.38 b	317.00 bb	357.38 a	26.86	313.33 b	336.50 a	18.05
Sem kg^{-1} (No.)	3338.13 aa	3174.38 a	2813.88 b	254.42	3207.08 a	3010.50 b	171.00
G (%)	98.87 a	98.87 aa	96.50 b	1.76	97.66 a	98.50 aa	1.18
REND (t ha^{-1})	4.45 b	5.81 bb	9.08 a	1.86	6.95 aa	5.93 a	1.25

MF: days until male flowering, FF: days until female flowering, PH: plant height, EH: ear height, PE: percentage of ear, PS: percentage of seed, CSY: commercial seed yield, TSW: thousand seed weight, S/kg: number of seeds per kilogram, G: standard germination and WS: hectoliter weight of seed. MSD: Minimum Significant Difference. Values in the same line for each source of variation, followed by the same letter, are not statistically different (Tukey, $P \leq 0.05$).

that the ratio is a determinant factor in seed production, and this is because when it is increased the quality and the seed yield is not sacrificed.

Table 4 shows the effect of the variables with regards to the genotypes and ratios. The response variables showed significant differences ($P \leq 0.01$) compared to the genotype (PE, PSE, PH, TSW, S/Kg, G, and REND), while in the ratios they only showed significance in variables TSW and S/Kg, which means that they influence the size and quality of the seed. Regarding the genotype × ratio interaction, there is significance in the percentage of the ear and the seed, as well as the seed yield, and with this combination there is a positive response. This response was similar to what was exposed by Virgen *et al.* (2014), Espinosa *et al.* (2003), Arellano *et al.* (2011). In this study, highly significant differences were observed in the parameters of seed yield and quality, the results shown agree with those reported by García *et al.* (2018), when revealing highly significant differences in physical and physiological quality.

The physiological quality can be evaluated with laboratory seed germination tests (Copeland and Mcdonald, 2001). In addition, the physical quality of the seed can be evaluated considering criteria such as moisture content, physical purity, mechanical damage, appearance, thousand seed weight, and volumetric weight, among other attributes (Tillmann *et al.*, 2003). When observing Table 5, corresponding to the means of the variables studied and their genotype × ratio interaction, as well as its effect on the seed quality and yield, it shows that there is difference between genotypes regarding the means of

Table 4. Mean squares and statistical significance of the variables analyzed.

S.V.	D.F..	Cobs (%)	Seed (%)	PH (kg hL^{-1})	TWS (g)	Seeds per kg (number)	SG (%)	Yield (t ha^{-1})
Genotype	2	122.65*	122.65*	50.16*	6874.04**	575483.16**	15.04*	45.30**
Proportion	1	17.10ns	17.10ns	5.15ns	3220.16*	231870.04*	4.16ns	6.20 ns
G*P	2	105.95*	105.95*	9.14ns	906.54ns	51800.66ns	6.54ns	25.07**
EE	18	12.50	12.50	5.46	443.36	39750.34	1.91	2.14
Mean		21.80	78.19	78.56	324.91	3108.79	98.08	6.44
CV		16.21	4.52	2.97	6.48	6.41	1.41	22.72

SV: source of variation; ns: not significant; * and ** significant values with $P \leq 0.05$ and $P \leq 0.01$, respectively.; DF: degrees of freedom; EE: Experimental error; CV: coefficient of variation; FM: days to male flowering, FF: days to female flowering, PH: plant height, TWS: thousand weight seeds, SG: standard germination.

Table 5. Means of the variables studied, corresponding to the genotype x ratio interaction, regarding the seed quality and yield.

Hybrid	Ratio Level	Cobs (%)	Seed (%)	PH (Kg hL^{-1})	TWS (g)	Seeds per kg (number)	SG (%)	Yield (t ha^{-1})
H-384A (G1)	4:2	31.07	68.92	77.09	295.0	3402	99.5	3.00
	6:2	20.98	79.01	79.46	305.7	3273	98.2	5.89
H-385A (G2)	4:2	17.14	82.85	81.96	311.5	3214	98.0	6.77
	6:2	19.46	80.54	80.43	322.5	3134	99.7	4.84
H-386A (G3)	4:2	19.73	80.26	75.24	333.5	3004	95.5	11.08
	6:2	22.44	77.56	77.18	381.2	2623	97.5	7.07

PH: plant height, TWS: thousand weight seeds, SG: standard germination.

the variables studied, although hybrid H-386A exceeds H-384A and H385A, with relation to the yield with 72.92% and 38.89%, respectively, in what corresponds to ratio 4:2, and with 16.69% and 31.54%, respectively in ratio 6:2; however, it stands out that statistically in the variables of seed quality (PE, PS, SHW, S/Kg and G), there are differences regarding the three hybrids (G1, G2 and G3), to which the numerical difference is not representative, with regards to the variables.

To cover the demand for seed requested from any seed company, it will always be necessary to determine the optimal conditions to achieve the maximum benefit. Virgen *et al.* (2016) pointed out that the loss in seed production can be attributed to the vigor of the lines, the variation of the environments, and the genotype x environment interaction, among others.

Likewise, the results observed indicate that the relationship there is between hybrid H-384A and H-385A, in relation to H-386A, can have an influence because the female parent defines or participates in both materials (B-4A×B-6A), as mentioned by Tadeo *et al.* (2004), in the variables and hybrids studied.

According to Ramírez *et al.* (2010), the environmental factors influence the growth and development of the plant. In this regard, the environment studied for seed production, Coquimatlan, Colima, shows good conditions to establish the three hybrids; however, the ratios 4:2 and 6:2 have a significant response between the materials and the variables, obtaining a better response from hybrid G3 in ratio 4:2. This is attributed to the low number of lateral primary branches (4-5), and with it the ramification of the spike from the male is lower than in the male parents of G1 and G2; however, through the mechanical dispersal of pollen the ratio 6:2 can be established to increase the yield in grain production without losing surface to be established, which is what happens when establishing four female furrows by two male furrows. Regarding this, García *et al.* (2014) mention that in their results they found that in the production of hybrid seed H-135 it is possible to use compact sowing patterns 4:1 and 8:1, and they found that the seed quality of the sowing patterns 4:1 and 8:1 is the same as that obtained by the conventional pattern 6:2, which is why in addition to taking advantage of the entire surface in the multiplication of the hybrid seed, they obtained good physical and physiological quality of the seed.

CONCLUSIONS

A large part of the success in seed depends on the production technology implemented. For this purpose, it is important to generate it, validate it, and make it reach the national seed-production companies and organizations; in this study, the behavior of the parents that participated in the yellow grain maize hybrids H-384A, H-385A and H-386A, with regards to the locality of Coquimatlan, Colima, covered the expectations of production and quality. However, when contemplating the topological arrangements or sowing ratios 4:2 and 6:2, the best ratio for seed production is R1 or 4:2; that is, four female furrows of and two male furrows, with hybrid H-386A being the one that obtained the best response. This allows making decisions regarding the establishment of the crop and quality in seed production lots, with it being a recommended environment in the influence area of the CIRPAC.

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