

Maize production as affected by sowing date, plant density and row spacing in the Bolivian Amazon

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Abstract: Slash and burn methodology is traditionally practised in the department of Pando (Bolivian Amazon). The main crops sowed soon after the slash are maize, rice, cassava and common beans. Two separate field experiments were carried out in 2008-2009 to determine the agronomic responses of maize to sowing date, plant population and row width. For the first experiment a split-plot design was used. Maize cultivar (Bayo Blando and Perla Pandino) was considered as main plots and the date of sowing as subplots. For the second experiment a split-split-plot design was used. Row spacing (0.5, 0.7 and 0.9 m) was considered as main plot, maize cultivar (Cubano Amrarrillo and Perla Pandino) as subplots, and plant density (5.0, 7.5 and 10 plant m⁻²) as sub-subplots. A significant reduction of grain yield was observed as the date of sowing (DS) delayed. Yield reduction of the second DS compared to the first, was 85 and 45% for Perla Pandino and Bayo Blando respectively. The importance of plant density as a function of the correct row spacing is clearly shown. With the row spacing in use in the considered area (0.9 m) and with the narrowest (0.5 m), the best yields were obtained with 10 plants m⁻² (5.5 t ha⁻¹). The following conclusions can be drawn from the present study: 1. A delay in the sowing date for maize by 15-20 days (compared to sowing immediately after the cutting of the virgin forest or the secondary forest) strongly reduces grain production. The cultivar Perla Pandino was the most susceptible with a reduction of 85%. Late sowing of maize (*mais de socorro*), is suitable only if intercropped with other crops in order to protect the soil from erosion. Traditionally, rice and cassava are intercropped with maize, even if common beans or a legume cover crop would be more advisable. 2. The density of maize may be increased up until 10 plants m⁻² in order to achieve the most productive results by using row spacings of 0.5 e 0.9 m, respectively, depending on the genotypes used. For varieties, with a reduced height such as Perla Pandino, it is

possible to use a more narrow row spacing, whilst for tall plants, over 2 m, such as Cubano Amarillo, a wider row spacing is recommended.

Key words: Maize, sowing date, row spacing, plant population, plant density, Bolivian Amazon.

Introduction

Pando is a fraction (termed department) of the Bolivian Amazon on the border with Brazil. This region is densely forested and the traditional cropping system in use is the typical slash and burn methodology. However, this system has been extensively changed over the last decades, thereby reducing the fallow period and resulting in a lower productivity. The main crops sown soon after the slashing of either virgin forest, or more often, after the secondary forest (*barbecho*) are maize, rice, cassava and common beans.

Key planting factors, influencing maize production, include the sowing date and plant distribution through both seed densities and row spacing. There is little information available on the behaviour of maize to these factors in the Bolivian Amazon when a subsistence cultivation is used (Ramírez *et al.*, 1960; Rodríguez *et al.*, 1968; Godoy *et al.*, 1993). Generally, the sowing date of maize in this area varies from the first days of October to early November. In the tropical areas, similar to those considered in these experiments, maize production decreases with delay in the sowing date, although dry matter remains unaffected (Medeiros *et al.*, 1980; Llanillo *et al.*, 1991; Zaki *et al.*, 1994). In addition, later sowing results in increased moisture contents of the fresh weight yield of straw but with concomitant decreases in the proportion of cobs in the total yield (Sikorskii *et al.*, 1987).

Variation of plant population is an option to increase grain yield of maize (Amaral Filho *et al.*, 2005). The correct plant arrangement design must be in compliance with practices of soil tillage and fertility, as well as water availability to increase the efficiency of photosynthetically active radiation (PAR). This index appears to be influenced only by plant densities and not row spacing (Kunz *et al.*, 2007). The results obtained thus far on the optimal maize sowing density in the humid tropics are highly variable. Some studies carried out in Brazil stressed that the use of plant population of approximately 9 plant m⁻² was a potential strategy to improve maize grain yield (Piana *et al.*, 2008), but other experiments reported a plant density of 4-6 plant m⁻² as optimal (Madeiros, *l. c.*). In addition to the row spacing, both soil fertility and timely soil fertilization applications, as well as weather patterns, were shown to greatly influence the dry matter accumulation of maize (Fulton, 1970). In the traditional cropping system of the area under consideration, wide rows (1.0 - 1.5 m) are used to allow intercropping with rice or cassava but in some cases, maize is sown as a specialized crop. In these cases, finding the optimum field plant density arrangement is essential

to maximize grain yield. Some authors report a row spacing of 0.7 -1.0 m as suitable for the best maize production (Medeiros, *l. c.*; Nafziger, 1994).

The objective of this study was to determine the agronomic responses of maize to sowing date, plant population and row width in the Departamento de Pando (Bolivia).

Material and methods

Experiment 1 - Date of sowing

The experiment was carried out in Oxisol in 2008-2009 at Porvenir, 30 km south of Cobija (Province Nicolás Suárez, Dipartimento de Pando, Bolivia) soon after the slashing and burning of a twelve year-old secondary forest (*barbecho*). Chemical analysis of the soil was carried out at the beginning of the experiment and the principle results are reported as follows: pH 4.7; P Olsen 1.1 ppm; total N 0.1 %; exch. Al, Ca, Mg and K: 4.6, 1.1 0.6 and 0.1 meq/100 g soil respectively; Al saturation 64%. Prior to sowing, the soil was double cross-harrowed using a four-row disc equipment. The experimental design was a randomized split-plot design with four replicates and plot size of 11.2 m x 30 m, which constituted the main factor (maize cultivar). Maize cultivars with decumbent leaves were *Bayo Blando* and *Perla Pandino*. According to the classification of Brandolini *et al.* (1990, 2004), these cultivars are included in the type *Amazónico*, characterized by tall and late maturing plants, long ears (with the exception of *Enano*), and floury or semi-vitreous seeds. These cultivars are mostly spread in the Amazon Basin and part of the Chaco region (150-1000 m asl). The subplots were 5.6 m wide (eight rows wide with 0.7 m row spacing) and 10 m long. The main plots were split into three sub-plots containing the standard density of 7.5 plant m⁻². The sowing dates of the three subplots were, respectively, as follows: I-October 8, 2008; II-October 28, 2008; III-November 17, 2008. No chemical fertilizers were added and weed control was carried out twice during the growing season using the technique of hand weeding. The sampling area was comprised of four central rows, each 3 m long. The morphological traits of the crop (plant height, ear insertion and ear per plant) were evaluated by considering an average of ten sample plants marked in each sampling plot. Flowering and ripening at 75% were recorded. The ANOVA was computed using MSTATC software according to a fixed effect model. Significant differences between means were tested by Duncan's multiple range test.

Experiment 2 - Row spacing and plant population

The second trial was carried out during the same period as the first trial. The experimental design was a randomized split-split-plot design with four replicates and a plot size of 16.8 m x 30 m which constituted the main factor (row spacing: 0.9, 0.7

and 0.5 m). The main plots were split into two sub-plots containing two cultivars (*Cubano Amarillo* - a synthetic genotype - and *Perla Pandino*) and three sub-sub-plots with plants densities of 5.0, 7.5 and 10 plant m⁻², respectively. An oversowing was carried out initially, and then seedlings were thinned out to the desired plant density. Seeds were sown on October 25. No chemical fertilizers were added and weed control was carried out three times (18, 52 and 76 days after sowing) using the hand weeding technique. Sampling area was comprised of four central rows, each 3 m long. Morphological traits of the crop (plant height, ear insertion and ear per plant) were evaluated by considering the average of ten sample plants marked in each sampling plot. Flowering and ripening at 75% were recorded. Samples of grain production were utilized to determine the 100 seed weight. The ANOVA was computed according to a fixed effect model. Significant differences between means were tested by Duncan's multiple range test.

Results and Discussion

Experiment 1

Significant differences attributed to the mean effect of the cultivar were observed for date of flowering, date of ripening and plant height (table 1). *Perla Pandino* was the cultivar with the latest date of flowering and latest date of ripening, corresponding to 79 and 134 days after sowing (DAS), respectively. The mean effects of date of sowing (DS) had significant effects on all the observed parameters (table 1).

Table 1 - Experiment 1. Mean effects of date of sowing and cultivar

TREATMENT	PLANT HEIGHT	EAR INSERTION	DATE OF FLOWERING	DATE OF RIPENING	EAR PER PANT
	(cm)	(cm)	(DAS) [#]	(DAS) [#]	(n)
<i>Date of Sowing (DS)</i>					
I	247 a	149 b	75 a	135 a	1.0 a
II	250 a	156 a	74 ab	129 ab	0.9 ab
III	214 b	149 b	67 c	124 c	0.8 b
<i>Cultivar (C)</i>					
Bayo Blando	249	149	65	125	0.9
Perla Pandino	226	154	79	134	0.9
f	**	ns	**	**	ns
DS x C	*	ns	**	**	ns

(#) Days After Sowing.

ns: not significant at P£0.05. *, **: significant at P£0.01 and P£0.05 respectively.

Means within rows followed by same letter (s) are not different at 5% level as per Duncan's test.

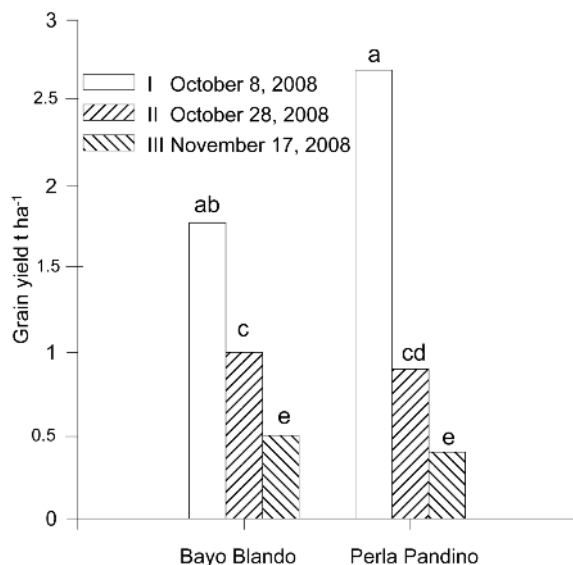


Figure 1 - Experiment 1. Grain yield of Bayo Blando and Perla Pandino according to date of sowing. Means within columns followed by same letter(s) are not different at 5% level as per Duncan's test.

The latest DSIII, when compared to DSI, showed a reduction in both plant height (-14%) and ear per plant (-20%). An earliness in flowering and ripening by a mean of 9.5 DAS was observed with the third DSIII compared to DSI. Grain yield of the tested cultivar significantly decreased with the delay in sowing date (figure 1).

Yield reduction in plants sown on the second DS corresponded to 85 and 45% for Perla Pandino and Bayo Blando, respectively, when compared to that obtained in plants sown on the first DS. This effect is due to both the shortening of the growing season, and to the reduction in the number of ears per plant. The significant yield decrease may have been caused by the gradual loss of soil fertility, that probably occurred in the period between DSI and DSII. This probability is based on the observation that, during this period, the soil showed a reduced coverage thus remaining subject to the erosive action of rainwater.

Experiment 2

The average effect of row spacing (table 2) had significant effects on plant height and on the date of ear insertion. Both characteristics increased between a distance of 0.5 m to 0.9 m. Above all, the results demonstrate that genotype is the principle source of variability of all the characteristics evaluated. Ear insertion was delayed by approximately 10 days in Cubano Amarillo, which was also the taller variety (+ 50 cm), in comparison to Perla Pandino.

Table 2 - Experiment 2 . Mean effects of the considered variables.

TREATMENT	PLANT HEIGHT AT 47 DAS [#] (cm)	LEAF NUMBER PER PLANT AT 47 DAS [#]	DATE OF FLOWERING (DAS) [#]	DATE OF RIPENING (DAS) [#]	PLANT HEIGHT (cm)	EAR INSERTION (cm)	100 SEED WEIGHT (g)
<i>Row spacing (RS)</i>							
0.5	68 a	10.8 a	66 a	126 a	193 b	112 b	24.5 a
0.7	82 a	11.2 a	67 a	127 a	195 ab	117 ab	24.5 a
0.9	68 a	11.0 a	66 a	126 a	202 a	120 a	24.4 a
<i>Cultivar (C)</i>							
Cubano Amarillo	77	10.6	72	132	222	147	28.7
Perla Pandino	68	11.4	61	121	169	85	20.3
<i>f</i>	*	**	**	**	**	**	**
<i>Plant density (PD)</i>							
5.0	75 a	11.4 a	66 a	126 a	196 a	119 a	24.3 a
7.5	71 a	10.9 a	66 a	126 a	203 a	117 a	24.9 a
10.0	72 a	10.7 a	66 a	126 a	188 a	112 a	24.2 a
<i>RS x C</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>
<i>RS x PD</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>
<i>C x PD</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>
<i>RS x C x PD</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>

(#) Days After Sowing.

ns: not significant at P£0.05. *, **: significant at P£0.01 and P£0.05 respectively.

Means within rows followed by same letter (s) are not different at 5% level as per Duncan's test.

Aside from the differences in average yield (4.21 t ha⁻¹ for Perla Pandino and 3.59 t ha⁻¹ for Cubano Amarillo), yield was significantly influenced by the interaction "row spacing x seed sensity" (figure 2) and "row spacing x variety" (figure 3).

The above mentioned sources of 'variability' were both significant at P£0.05. The importance of plant density as a function of the correct row spacing is clearly shown. With the row spacing in use in the considered area (0.9 m) and with the narrowest (0.5 m), the best yields were obtained with 10 plants m⁻² (5.5 t ha⁻¹). Using a row spacing of 0.7 m, no differences in yields were obtained with all plant densities (average of 3.6 t ha⁻¹). As regards the second interaction (figure 3), the best row spacing for Perla Pandino and Cubano Amarillo was 0.5 m and 0.9 m, respectively.

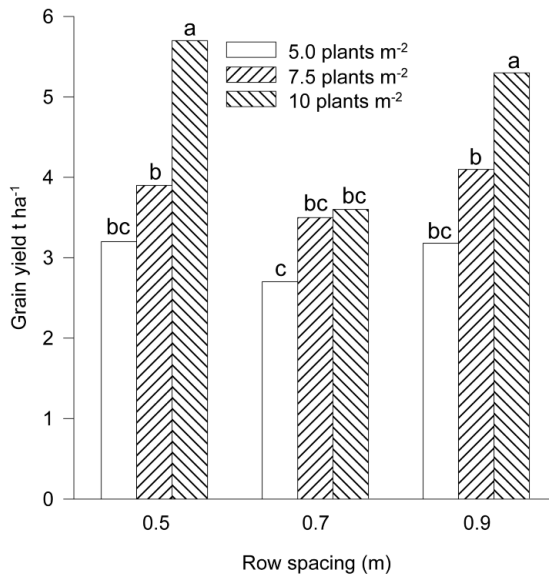


Figure 2 - Experiment 2. Grain yield according to row spacing and plant density.

Means within columns followed by same letter(s) are not different at 5% level as per Duncan's test.

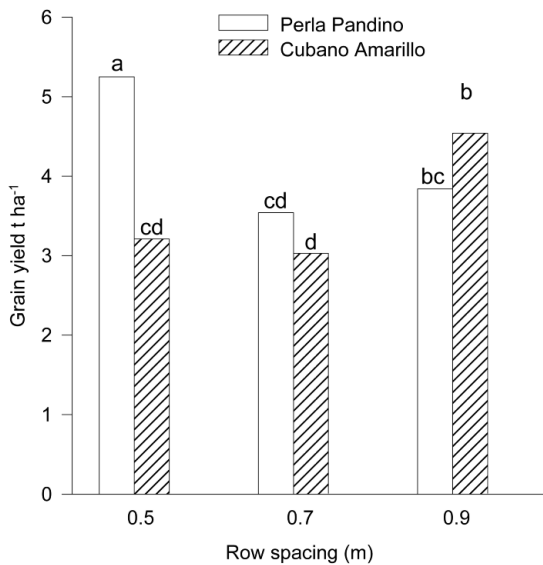


Figure 3 - Experiment 2. Grain yield of Perla Pandino and Bubano Amarillo according to row spacing.

Means within columns followed by same letter(s) are not different at 5% level as per Duncan's test.

Conclusions

The following conclusions can be drawn from the present study: 1. A delay in the sowing date for maize by 15-20 days (compared to sowing immediately after the cutting of the virgin forest or the secondary forest) strongly reduces grain production. The cultivar Perla Pandino was the most susceptible with a reduction of 85%. Late sowing of maize (*mais de socorro*) is only suitable if intercropped with other crops in order to protect the soil from erosion. Traditionally, rice and cassava are intercropped with maize, even if common beans or a legume cover crop would be more suitable. The use of green manure is a well-known method for improving soil fertility in the humid tropics (Rodgers and Giddens, 1957; Wade and Sanchez 1983; De-Polli and Chada, 1989). Adding plant residues (mostly legumes), is useful to increase soil fertility in the case of late maize sowing. According to previous research (Casini and Pastén, 2004), carried out in the same area of the present study, incorporation of kudzu (*Pueraria phaseoloides* (Roxb.) Bent) and mucuna (*Mucuna pruriens* var. *utilis* (L.) DC) increased maize yield compared to the control (bare soils). Legume residues constitute a rapidly available N source which, according to Carsky (1989), can result in a 25-45% increase in maize grain production. In addition, decomposing legume cuttings are also shown to decrease Al saturation (Wade and Sacher, l. c.), as result which was confirmed by Casini and Pastén (l. c.). 2. The density of maize may be increased up until 10 m⁻² in order to achieve the most productive results by using row spacings of 0.5 and 0.9 m, respectively, depending on the genotypes used. For varieties, with a reduced height such as Perla Pandino, it is possible to use a more narrow row spacing, whilst for tall plants, over 2 m, such as Cubano Amarillo, a wider row spacing is recommended. These results are in contrast with those reported by some authors. According to Afferri *et al.* (2008), ear height and yield are not influenced by row spacing and plant density. On the other hand, Marchao *et al.* (2005) reported that grain yield is increased by increasing plant population. 3. Additional experiments are necessary in order to ascertain the best approach for maintaining maize yield potential in the humid tropics with late sowing dates and by taking into consideration the positive perspectives provided by mulching and green manuring.

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