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Article

# Yield of forage, grain and biomass in eight hybrids of maize with different sowing dates and environmental conditions

# Rendimiento de forraje, grano y biomasa en ocho híbridos de maíz con diferentes fechas de siembra y condiciones ambientales

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**Abstract:**

The aim was to evaluate yield of forage, grain and biomass and fibre content of eight hybrids of maize (Rio-Grande, Arrayan, Genex 778, Narro 2010, Advance 2203, DAS 2358, P4082W and HT9150W) during two sowing seasons (spring/summer) for two consecutive years at La Laguna in Torreon, Mexico. Once the grain progression of the kernel milk line was ⅓, green forage yield (GFY), dry matter (DM), neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined. When the corncobs were fully mature, grain yield (GY) and biomass production (TBP) were determined. Weather conditions were recorded during the experiment. The results indicated that maximum temperature was higher and rainfall lower in the summer sowing and second year. Spring sowing had significantly higher yields of GFY, DM, GY and TBP compared to summer sowing. The first year of study showed significantly higher yields regarding GFY, GY and TBP, but FDN, FDA, DM content compared to the second year. The best hybrid for GFY and DM was Rio-Grande; for FDN and FDA was Advance 2203; for GY was HT9150W and finally for TBP was Arrayan. Regardless of the hybrid used and the sowing season, production of maize depended on external factors such as maximum temperature and rainfall; therefore, producers need to consider sowing in spring to avoid the negative effect of high temperatures on plant development.

**Key words**: *Zea mays* L., Sowing season, Hybrid, Yield.

**Resumen:**

El objetivo fue evaluar la producción de forraje, grano, biomasa y contenido de fibra de ocho híbridos de maíz (Rio-Grande, Arrayan, Genex 778, Narro 2010, Advance 2203, DAS 2358, P4082W and HT9150W) durante dos épocas de siembra y dos años consecutivos. Cuando el grano estaba en estado lechoso-masoso, se determinó la producción de forraje en verde (PFV), materia seca (MS), fibra detergente neutro (FDN) y ácido (FDA). Cuando la mazorca estaba madura, se determinó la producción de grano (PG) y la biomasa (BIO). Adicionalmente, en el área de estudio, se obtuvieron datos ambientales (temperaturas y precipitación). Los resultados indican que la máxima temperatura fue superior y la precipitación menor en la siembra de verano y en el segundo año. La siembra de primavera fue superior para PFV, MS, PG y BIO ($P$<0.05) en comparación con la siembra de verano. El primer año de estudio fue superior al segundo en PFV, PG, BIO ($P$<0.05) pero no en FDN, FDA y MS. El mejor híbrido para PFV y MS fue Rio-Grande; para FDN y FDA fue Advance2203, para PG fue HT9150W y finalmente para BIO fue Arrayan.

Independientemente de la variedad y de la fecha de siembra, es evidente que la producción de forraje y grano de maíz dependen de los factores externos temperatura y precipitación; por lo tanto, los productores necesitan considerar la siembra de primavera como una alternativa para incrementar la producción y evitar el efecto negativo de las altas temperaturas sobre el desarrollo de las plantas.

**Palabras clave:** *Zea mays* L., Fecha de siembra, Variedad, Producción.

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# Introduction

Maize (*Zea mays L.*) is after wheat and rice the most important crop in various parts of the world(1) and has the ability of adaptation to different climatic and soil conditions(2,3,4). In industrialized countries its uses are mainly for forage production, raw material for the production of processed foods, and recently, for ethanol production(5,6,7).

The yield and quality of maize depend on soil fertility(8), crop management(9,10) and genetics(11,12). Forage maize is considered an excellent food for ruminants for its high energy and protein content(13). However, in Mexico, maize silage has a lower energy value for lactation because previous breeding focussed on increasing forage yield rather than forage quality for dairy production(14).

In La Laguna area, a dairy basin in Mexico, more than 30,000 ha of maize are grown under irrigation and about 1,000 ha under rainfed conditions(15). The demand for forage maize in dairy farms, located in this area, is high and there is a need to identify hybrids with both good forage quality and high biomass production potential, because the forage of maize constitutes 30 to 40 % of the daily diet of the dairy cattle(16).

Despite the importance of production of forage maize in La Laguna, there are few reports comparing the quality (crude protein, fiber, and digestibility of dry matter) and yield of commercial hybrids(17,18). Seed companies and research institutions are constantly releasing new hybrids to the market; therefore, it is necessary to evaluate them for their production potential under different environmental conditions and thereby to select the hybrids with the best adaptability, yield and chemical composition for animal production. Thus, the objectives were to evaluate: 1) the green forage yield, fiber content, 2) grain yield and 3) biomass yield of eight hybrids of maize (Rio Grande, Arrayan, Genex 778, Narro 2010, Advance 2203, DAS 2358, P4082W and HT9150W) in two sowing seasons (spring and summer) for two consecutive years under irrigation in the dairy basin of La Laguna. The hypothesis was that season, year of sowing and hybrids used do not affect green forage yield, fibre content, grain yield and biomass yield.

# Material and methods

## Experimental site

The study was conducted in the experimental field of the Universidad Autónoma Agraria Antonio Narro in La Laguna (25° 23' 36.24" N, 101° 0' 1.8" W and 1,120 m asl) for two consecutive years (2010 and 2011). In Table 1, presents the average monthly maximum, minimum and mean temperature, heat units and rainfall that occurred during the experimental period.

**Table 1.** Temperature (maximum, minimum and mean), heat units [HU] and rainfall at La Laguna region during 2010 and 2011*

| | 2010 | | | | | 2011 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month | Max | Min | Mean | HU | Rainfall | Max | Min | Mean | HU | Rainfall |
| | Temperature (ºC) | | | | (mm) | Temperature (ºC) | | | | (mm) |
| Apr | 31.7 | 14.3 | 23.3 | 400.8 | 12.4 | 35.1 | 15.0 | 25.8 | 475.2 | 0.0 |
| May | 35.4 | 18.1 | 27.3 | 536.6 | 13.8 | 35.3 | 18.0 | 27.2 | 534.4 | 0.6 |
| Jun | 35.6 | 21.7 | 28.8 | 564.6 | 50.4 | 36.3 | 21.5 | 29.7 | 592.8 | 0.0 |
| Jul | 32.0 | 21.2 | 26.4 | 508.1 | 102.2 | 34.3 | 22.1 | 28.4 | 569.8 | 0.8 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Aug | 35.1 | 22.0 | 28.9 | 584.7 | 2.4 | 35.9 | 22.7 | 29.7 | 609.8 | 6.4 |
| Sept | 31.9 | 19.4 | 25.6 | 468.3 | 69.8 | 33.2 | 18.3 | 26.4 | 491.4 | 1.2 |
| Oct | 30.2 | 11.5 | 21.2 | 346.3 | 0.0 | 30.9 | 14.1 | 22.7 | 392.8 | 0.0 |
| Nov | 26.2 | 5.8 | 15.9 | 177.0 | 0.0 | 26.2 | 7.9 | 17.1 | 212.7 | 0.2 |

* For the area of La Laguna, the rainfall recorded in 2010 was within normal range; however, the rainfall registered in 2011 was below normal range.

## Hybrids and crop management

Prior to the establishment of the experiments in both years, spatial heterogeneity in soil nutrient status from previous crops were balanced by sowing oats in the fall-winter cycle. Crop rotation profoundly modify the soil environment by reducing the incidence of diseases, pest or weeds and influencing crop growth and yield(19). The soil was prepared with fallow, tracking and levelled, followed by dug furrows at 0.75 m spacing and 0.1 m deep with a plow. The soil is a loamy-sand with a pH of 7.6.

It was evaluated the maize hybrids Rio Grande, Arrayan, Genex 778, Narro 2010, Advance 2203, DAS 2358, P4082W and HT9150W. These hybrids are widely grown in the region because they were tested and released for production areas like this one. Sowings were done on May 4 and July 1 in 2010 and April 13 and June 13 in 2011. The seed was hand-sown at 3 cm depth. In both seasons and years, the sowings were carried out under dry soil conditions, then irrigated to a depth of 10 cm. Two seeds every 20 cm were planted and 23 d later, thinning was carried out to achieve a population of 88,000 plants per hectare(20). Additionally, the experiments were hand-weeded 28 d after sowing in both years. The experimental plot, for forage and grain, in each replicate consisted of one central furrow by 3 m (2.25 $m^2$), in order to harvest plants in full competition. Four repetitions of each hybrid were sown. The total plot area for each replicate was 12 $m^2$ consisting of four furrows, 4 m long.

During both sowing seasons and years, four irrigations to a 70 cm depth were applied using furrow irrigation system. The irrigation depended on the phenological stage of the crop as described in Table 2. In addition, nitrogen and phosphorus were provided during both sowing seasons and years; 150 kg/ha of nitrogen (Urea [$CO(NH_2)_2$]; 50% at sowing and 50% before the second irrigation) and 80 kg/ha of phosphorus (fosfato monoamonico [$NH_4H_2PO_4$]; all at sowing time). Accordingly, to the soil analysis, fertilization with potassium was not necessary. The presence and incidence of pests and weeds were monitored and controlled with several chemical products, using a GIBER® GM-20 sprayer.

The forage was hand-harvested when the grain progression of the kernel milk line was ⅓[21]. This occurred 90 days after sowing (das) in spring 2010; 97 das in summer 2010; 94 das in spring 2011 and 92 das in summer 2011.

Shelling was carried out by hand and the biomass was estimated when corncobs were fully mature. Full maturity was considered when the moisture content of seeds was 12 % measured with a moisture meter (SHORE®). This occurred 136 das in spring 2010; 149 das in summer 2010; and 131 das in both seasons of 2011.

**Table 2:** Irrigations applied in the crops of the experiments conducted in the region of La Laguna during the years of 2010 and 2011

| | 2010 | | 2011 | |
|---|---|---|---|---|
| Irrigation No. | Spring (das) | Summer (das) | Spring (das) | Summer (das) |
| 1st | 16 | 21 | 15 | 15 |
| 2nd | 34 | 41 | 38 | 37 |
| 3rd | 52 | 59 | 60 | 59 |
| 4th | 78 | 80 | 81 | 80 |

das= Days after sowing.

## Response variables

In both seasons and years, the following variables were determined: days to male flowering, days to female flowering, plant height, corn ear height, green forage yield, dry matter content, neutral and acid detergent fiber, grain yield, biomass production and distribution of plant organs.

The green forage yield is the addition of weight of leaves and stems plus maize ears, which were harvested and counted separately. The content of dry matter was assessed by taking randomly three whole plants per plot. The samples were sun dried for 3 d and subsequently transferred to a digital oven (FELISA®) at 65 °C for 24 h. Dry samples were ground in a mill through a 3 mm screen (NOGUEIRA®). A sub-sample of the dried and ground sample was analysed by the method of Van Soest *et al*[22] to determine neutral detergent fiber and acid detergent fiber.

From the experimental plot it was counted the number of plants and maize ears produced. For the grain yield, all the corn ears were threshed and weighted the grains (kernels). For the agronomic variables of the maize ears, three maize ears per experimental plot were used and the following variables measured: weight, length, diameter and number of rows per ear, number of grains in three rows per ear. Finally, for the agronomic variables of the grains, width, length, thickness, diameter and weight of the corncob and weight of the grain per ear were measured.

Biomass yield and the relative proportion of yield components were obtained when the plants were fully mature; for this, two plants per plot were taken and separated into leaves, stems, corn ear, husks and tassel and subsequently dried at 70 °C in a digital oven (FELISA®) for 24 h.

The variables assessed in units of mass ≤ 0.5 kg were weighed on a precision balance (0.5 x 0.001 kg; TRANSCELL Technology®). The variables assessed in units of mass ≥ 0.5 kg were weighed using a digital scale (30 x 0.02 kg; REVUELTA®). The units of length were measured with a vernier (0.15 m; TRUPER®) and metal ruler (0.30 m); height of plants and maize ears were measured with a 4 m length metal ruler.

## Statistical analyses

The experimental design used in both experiments was a complete block with four repetitions. The model that explains each observation was:

$$Y_{ij} = \mu + \tau_i + \beta_j + \epsilon_{ij}$$

**Here:**

**μ** represents the general mean;

**$\tau_i$** represents the effect of treatment i (i = 1,….t).

**$\beta_j$** represents the effect of block j (j = 1,….b);

**$\epsilon_{ij}$** are the residuals.

Differences among fixed effects (sowing season, year and hybrid) to compare means were analysed by variance (PROC ANOVA; SAS version 9.3)[23] with Tukey test at the same level when statistical difference was detected ($P$<0.05). The data of the sowing season were combined for the variable year. For the season variable, the data of the years were combined. For the hybrid variable, the data of sowing seasons and years were combined. All two-way interactions among the fixed effects were included in each analysis. Non-significant ($P$>0.05) interactions were removed from the analysis.

# Results

## Forage variables and yield, dry matter and fiber content

The interaction among hybrids, year and season of sowing influenced the variables for days to male ($P$<0.01) and female flowering ($P$<0.01), whereas for the rest of the variables the triple interactions were not significant (Table 3).

The interaction between sowing seasons and years influenced weight of fresh plants, weight of fresh corn ear, green forage yield and content of NDF and ADF ($P$<0.05 to $P$<0.01); however for the rest of the variables the interactions were not significant. Most of the interactions evaluated for hybrids and years differed ($P$<0.05 to $P$<0.01); however, plant height and fresh plant weight did not. Similarly, most of the interactions evaluated for hybrids and sowing season differed ($P$<0.05 to $P$<0.01); however, ear height, green forage yield and dry matter production were not significant.

Days to male and female flowering, plant and corn ear height, weight of fresh plants and fresh corn ear, and green forage yield and dry matter production differed between years ($P$<0.01), between sowing seasons ($P$<0.01) and among hybrids ($P$<0.01); but dry matter production did not differ between years ($P$>0.05). The percentage of NDF and ADF among hybrids was significant for year, sowing season and hybrids ($P$<0.05 to $P$<0.01).

**Table 3:** Days to male (MF) and female flowering (FF), plant height (PH), corn ear height (CH), weight of fresh plants (FP), weight of fresh corn ear (CF), green forage yield (FY), dry matter content (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF) of eight hybrids of maize sown on two different seasons in two years

| | Variables | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | MF | FF | PH | CH | FP | CF | FY | DM | NDF | ADF |
| | Days | | cm | | t ha$^{-1}$ | | | | % | |
| Sowing Season/P value | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| Spring | 76 | 78$^{a}$ | 227$^{a}$ | 121$^{a}$ | 49.6$^{a}$ | 25.7$^{a}$ | 75.3$^{a}$ | 20.2$^{a}$ | 46$^{b}$ | 23$^{b}$ |
| Summer | 68 | 70$^{b}$ | 193$^{b}$ | 103$^{b}$ | 34.3$^{b}$ | 18.6$^{b}$ | 52.9$^{b}$ | 13.7$^{b}$ | 63$^{a}$ | 39$^{a}$ |
| Year/P value | ** | ** | ** | ** | ** | ** | ** | NS | * | * |
| 2010 | 70$^{b}$ | 73$^{b}$ | 213$^{a}$ | 110$^{b}$ | 44.3$^{a}$ | 23.9$^{a}$ | 68.2$^{a}$ | 17.5 | 46$^{b}$ | 24$^{b}$ |
| 2011 | 73$^{a}$ | 75$^{a}$ | 207$^{b}$ | 115$^{a}$ | 39.6$^{b}$ | 20.36$^{b}$ | 59.9$^{b}$ | 16.3 | 55$^{a}$ | 31$^{a}$ |
| Year*Season | NS | NS | NS | NS | ** | ** | ** | NS | * | * |
| Hybrid/P value | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| Rio Grande | 75$^{a}$ | 77$^{a}$ | 209$^{bc}$ | 111$^{bc}$ | 47.9$^{a}$ | 25.1$^{a}$ | 72.9$^{a}$ | 19.2$^{a}$ | 53$^{b}$ | 30$^{b}$ |
| HT9150W | 74$^{ab}$ | 77$^{a}$ | 208$^{bc}$ | 105$^{c}$ | 43.6$^{ab}$ | 25.2$^{a}$ | 68.7$^{ab}$ | 17.9$^{ab}$ | 52$^{d}$ | 30$^{b}$ |
| Genex778 | 68$^{d}$ | 71$^{d}$ | 209$^{bc}$ | 123$^{a}$ | 44.3$^{ab}$ | 21.6$^{b}$ | 65.9$^{bc}$ | 16.6$^{b}$ | 58$^{a}$ | 34$^{a}$ |
| Arrayan | 70$^{c}$ | 72$^{c}$ | 215$^{ab}$ | 112$^{b}$ | 45.2$^{ab}$ | 20.5$^{bc}$ | 65.6$^{bc}$ | 16.8$^{b}$ | 56$^{ab}$ | 31$^{ab}$ |
| P4082W | 74$^{ab}$ | 76$^{b}$ | 222$^{a}$ | 121$^{a}$ | 43.4$^{ab}$ | 20.9$^{bc}$ | 64.7$^{bc}$ | 16.8$^{b}$ | 57$^{ab}$ | 37$^{a}$ |
| DAS 2358 | 74$^{ab}$ | 77$^{a}$ | 204$^{cd}$ | 111$^{b}$ | 39.3$^{c}$ | 25.2$^{a}$ | 64.5$^{bc}$ | 17.1$^{b}$ | 52$^{d}$ | 29$^{c}$ |
| Narro 2010 | 70$^{c}$ | 73$^{c}$ | 217$^{a}$ | 118$^{a}$ | 42.8$^{bc}$ | 19.5$^{bc}$ | 62.4$^{c}$ | 17.2$^{b}$ | 55$^{b}$ | 30$^{b}$ |
| Advance2203 | 68$^{d}$ | 70$^{e}$ | 197$^{d}$ | 97$^{d}$ | 28.6$^{d}$ | 19.2$^{c}$ | 47.8$^{d}$ | 13.6$^{c}$ | 50$^{d}$ | 27$^{c}$ |
| P value Hybrid*Year | ** | ** | NS | ** | NS | ** | * | ** | * | * |
| P value Hybrid*Season | ** | * | ** | ** | NS | ** | NS | NS | * | * |
| P value Hybrid*Year*Season | ** | ** | NS | NS | NS | NS | NS | NS | NS | NS |

For the year variable, the data of the sowing seasons were combined. For the season variable, the data of the years were combined. For the hybrid variable, the data of sowing seasons and years were combined.

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$; NS $P > 0.05$; NA= not applicable.

ab Values with different superscript differ ($P<0.05$).

## Grain variables and yield

The interaction among hybrids, year and season of sowing were significant for the variables grain yield (P<0.01), corn ear yield (*P*<0.01), corn ear diameter (*P*<0.01) and number of grains per row (*P*<0.01); whereas the rest of the variables were not significant (Table 4). The interaction between sowing seasons and years were significant for almost all variables evaluated for grain (*P*<0.05 to *P*<0.01); however, number of rows per corn ear did not differ statistically between sowing season and between years (*P*>0.05). Interactions between hybrids and years differed for all the variables assessed (*P*<0.05 to *P*<0.01). On the contrary, the interactions between hybrid and sowing season were significant for grain yield, corn ear yield, corn ear diameter and number of grains per row (*P*<0.01) and the rest of the variables were not significant (*P*>0.05).

**Table 4:** Grain yield (GY; kernels), corn ear yield (CY; corn ear [kernels + corncob]), corn ear length (CL), individual corn ear weight (ICW), grain weight per corn ear (GWC), corncob weight (CBW), corn ear diameter (CD), corncob diameter (CBD), number of rows per corn ear (NRC), number of grains per row (NGR) of eight hybrids of maize sown on two different seasons in two consecutive years

| | **Variables** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **GY** | **CY** | **CL** | **ICW** | **GWC** | **CBW** | **CD** | **CBD** | **NRC** | **NGR** |
| | t ha$^{-1}$ | | cm | g | | | mm | | n | |
| Sown season/*P* value | ** | ** | ** | * | ** | ** | ** | ** | NS | ** |
| Spring | 9.9$^{a}$ | 11.9$^{a}$ | 17$^{a}$ | 217$^{a}$ | 193$^{a}$ | 29$^{a}$ | 48$^{a}$ | 26$^{a}$ | 15 | 38.5$^{a}$ |
| Sumer | 7.2$^{b}$ | 9.8$^{b}$ | 15$^{b}$ | 189$^{b}$ | 154$^{b}$ | 21$^{b}$ | 37$^{b}$ | 20$^{b}$ | 15 | 32.0$^{b}$ |
| Year/P value | ** | * | ** | NS | ** | * | * | * | NS | * |
| 2010 | 7.9$^{a}$ | 10.8$^{a}$ | 16$^{a}$ | 208 | 182$^{a}$ | 27.5$^{a}$ | 47$^{a}$ | 25$^{a}$ | 15 | 36.5$^{a}$ |
| 2011 | 6.9$^{b}$ | 9.3$^{b}$ | 12$^{b}$ | 206 | 165$^{b}$ | 23.2$^{b}$ | 42$^{b}$ | 19$^{b}$ | 15 | 29.0$^{b}$ |
| Year*Season | ** | ** | * | ** | ** | ** | ** | ** | NS | ** |
| Hybrid/P value | ** | ** | NS | ** | ** | ** | ** | ** | ** | ** |
| Rio Grande | 9.4$^{ab}$ | 12.3$^{a}$ | 17 | 216$^{a}$ | 186$^{ab}$ | 29$^{ab}$ | 48$^{bc}$ | 27$^{a}$ | 16$^{abc}$ | 39$^{a}$ |
| HT9150W | 9.9$^{a}$ | 11.8$^{a}$ | 16 | 229$^{a}$ | 202$^{a}$ | 29$^{ab}$ | 51$^{a}$ | 27$^{a}$ | 16$^{a}$ | 36$^{bcd}$ |
| Genex778 | 5.5$^{d}$ | 8.2$^{c}$ | 15 | 112$^{c}$ | 130$^{c}$ | 27$^{b}$ | 45$^{d}$ | 24$^{bc}$ | 15$^{bcd}$ | 36$^{c}$ |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Arrayan | $8.9^{b}$ | $11.8^{a}$ | 16 | $228^{a}$ | $198^{ab}$ | $31^{ab}$ | $50^{a}$ | $27^{a}$ | $16^{ab}$ | $35^{cd}$ |
| P4082W | $9.4^{ab}$ | $12.8^{a}$ | 16 | $215^{a}$ | $193^{ab}$ | $32^{a}$ | $49^{ab}$ | $27^{a}$ | $17^{a}$ | $38^{a}$ |
| DAS 2358 | $9.5^{ab}$ | $11.1^{a}$ | 17 | $215^{a}$ | $189^{ab}$ | $27^{b}$ | $46^{cd}$ | $25^{b}$ | $15^{cd}$ | $39^{a}$ |
| Narro 2010 | $7.8^{c}$ | $10.3^{b}$ | 17 | $208^{a}$ | $179^{b}$ | $29^{ab}$ | $45^{d}$ | $25^{b}$ | $14^{e}$ | $38^{ab}$ |
| Advance2203 | $7.0^{c}$ | $8.8^{c}$ | 16 | $169^{b}$ | $150^{c}$ | $19^{c}$ | $44^{e}$ | $23^{c}$ | $15^{de}$ | $34^{d}$ |
| *P* value Hybrid*Year | ** | ** | * | ** | ** | ** | ** | ** | * | ** |
| *P* value Hybrid*Season | ** | ** | NS | NS | NS | NS | ** | NS | NS | ** |
| *P* value Hybrid*Year*Season | ** | ** | NS | NS | NS | NS | ** | NS | NS | ** |

For the year variable, the data of the sown seasons were combined. For the season variable, the data of the years were combined. For the hybrid variable, the data of sown seasons and years were combined.

* $P\leq0.05$; ** $P\leq0.01$; *** $P\leq0.001$; NS $P>0.05$; NA= not applicable.

abcd Letters with different superscript differ ($P<0.05$).

Almost all variables on grain (grain yield, corn ear yield, corn ear length, grain weight per corn ear, corncob weight, number of grains per row) were significant for by sowing season, year and hybrid ($P<0.05$). Individual corn ear weight and number of rows per corn ear did not differ between years ($P>0.05$). Similarly, number of rows per corn ear did not differ between sowing season and hybrid did not influence the length of the corn ear.

## Biomass variables and yield

The interaction among hybrids, year and season of sowing were significant for almost all the variables for biomass and its components ($P<0.01$), except for the variable husks weight that was not significant ($P>0.05$, Table 5). All the interactions between season and year of sowing were significant ($P<0.05$ to $P<0.01$), except for the weight of husks. All the interactions between year of sowing and hybrids were significant ($P<0.05$ to $P<0.01$); however, none of the interactions between season and hybrid were significant. Biomass production, the weight of corn ear, stem, leaf and tassel were significant for sowing season, year and hybrid ($P<0.05$ to $P<0.01$). Weight of husks was significant only for hybrid ($P<0.01$) and not by the rest of variables ($P>0.05$).

**Table 5:** Biomass production (BP), corn ear weight (EW), stem weight (SW), leaf weight (LW), husks weight (BW) and tassel weight (TW) of eight hybrids of maize sown on two different seasons (spring and summer) in two consecutive years

| | Variables | | | | | |
|---|---|---|---|---|---|---|
| | **BP** | **EW** | **SW** | **LW** | **BW** | **TW** |
| | kg $m^{-1}$ | | g $m^{-1}$ | | | |
| Sown season/*P* value | * | * | ** | ** | NS | ** |
| Spring | $2.8^{a}$ | $1.7^{a}$ | $464^{a}$ | $381^{b}$ | 178 | $36^{a}$ |
| Summer | $2.6^{b}$ | $1.6^{b}$ | $341^{b}$ | $468^{a}$ | 174 | $30^{b}$ |
| Year/*P* value | * | * | ** | ** | NS | * |
| 2010 | $2.5^{a}$ | $1.5^{a}$ | $452^{a}$ | $346^{b}$ | 170 | $32^{b}$ |
| 2011 | $2.2^{b}$ | $1.3^{b}$ | $352^{b}$ | $425^{a}$ | 170 | $35^{a}$ |
| Season*Year | ** | ** | * | ** | NS | * |
| Hybrid/*P* value | ** | * | ** | ** | ** | ** |
| Rio Grande | $2.7^{b}$ | $1.6^{ab}$ | $377^{c}$ | $447^{ab}$ | $192^{bc}$ | $43^{a}$ |
| HT9150W | $2.7^{b}$ | $1.7^{ab}$ | $417^{bc}$ | $388^{bc}$ | $150^{bc}$ | $27^{cd}$ |
| Genex778 | $2.8^{b}$ | $1.6^{ab}$ | $400^{bc}$ | $481^{a}$ | $256^{a}$ | $41^{a}$ |
| Arrayan | $3.3^{a}$ | $1.9^{a}$ | $584^{a}$ | $485^{a}$ | $199^{b}$ | $43^{a}$ |
| P4082W | $2.8^{a}$ | $1.7^{ab}$ | $485^{b}$ | $475^{a}$ | $188^{bc}$ | $32^{bc}$ |
| DAS 2358 | $2.6^{b}$ | $1.8^{ab}$ | $345^{c}$ | $344^{cd}$ | $140^{cd}$ | $24^{d}$ |
| Narro 2010 | $2.7^{b}$ | $1.5^{bc}$ | $401^{bc}$ | $481^{a}$ | $185^{bc}$ | $37^{ab}$ |
| Advance2203 | $1.9^{c}$ | $1.3^{c}$ | $211^{d}$ | $295^{d}$ | $99^{d}$ | $16^{e}$ |
| *P* value/ Hybrid*Year | ** | ** | ** | * | * | * |
| *P* value/ Hybrid*Season | NS | NS | NS | NS | NS | NS |
| *P*/ Hybrid*Season*Year | ** | ** | ** | ** | NS | ** |

For the year variable, the data of the sowing seasons were combined. For the season variable, the data of the years were combined. For the hybrid variable, the data of sowing seasons and years were combined.

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$; NS $P > 0.05$; NA no applicable.

abc Letters with different superscript differ statistically ($P < 0.05$).

# Discussion

The green forage yield, dry matter and fiber content of the evaluated hybrids differed according to the season and year of sowing and hybrid; therefore, the first hypothesis is rejected. According to the results, spring sowing was more productive than summer sowing; but had a lower content of neutral and acid detergent fiber. This support the results of Reta *et al*[24] who observed that the yield of crops planted in spring was higher than the yield of crops planted in summer. Even though, the yield differed between sowing seasons, the yield recorded in summer was similar to previous reports for this sowing season[25]. Furthermore, it was observed a difference in temperature between sowing season and between years. It is likely that high temperatures, especially in summer, have caused a stress in plants, which accelerated the physiological development resulting in inhibiting plant growth and reducing the leaf area[26-29]; therefore affecting the weight of stem and leaves and its fiber content[30,31]. It was assumed that the heat units accumulated during the plant growth influenced the male and female flowering in both sowing seasons; this agrees with the difference observed among hybrids in green forage yield and dry matter. Extreme temperatures are associated with increased vapour pressure deficit, which contributes to water stress. Water stress promoted a faster development in plants that results in smaller plants due to a shorter life cycle, hence, shorter reproductive duration and, consequently, lower yield potential[29]. Therefore, this could have contributed to increase biomass accumulation during the vegetative stage.

Rainfall is another external factor that might have contributed to production. The records indicated that rainfall was higher in the first year than the second year (251 mm *vs* 9.2 mm); consequently, the overall production was higher in the first year compared to the second year independently of the irrigation provided during the experiment. The irrigation provided during the experiment was similar on both years in order to provide similar management conditions and without influencing the outcome. Thus; both external factors (temperature and rainfall) influenced directly the development and production of the plants; because there are a positive relationships among plant height, forage yield, dry matter and fiber content[32-34]. For animal production, producers need to consider the sowing season in order to obtain an adequate forage yield and nutritional value aimed to increase the animal productivity[17,35,36].

The grain yield was influenced by the season and year of sowing and hybrid; therefore, the second hypothesis is rejected. Despite the variation in yield observed between seasons and years and among hybrids; the average production of grain was higher than average grain yield reported for this area, region and nationwide[15]. As previously reported for forage yield, dry matter and fiber content, it was assumed that the grain and corn ear yield were influenced by external factors (mainly temperature and rainfall). Grain and corn ear yield were higher in spring rather than summer sowing and were higher in the first year rather the second year of the experiment. These results are consistent with previous reports that indicated that rainfall directly influenced the total production of maize due to increases in the distribution, density and depth of the roots[37]. Moreover, extreme temperatures affect directly the grain weight[38,39] and yield[40-43]. Heat stress reduced maize grain weight due to proportional losses in grain composition (starch, protein and oil contents) and due to its direct effect during the grain-filling period, which caused a cessation of grain filling[43-44]. Moreover, heat stress reduced maize grain yield due to its negative effect on plant growth and development by increasing the abortion of fertilized structures[45,46].

The differences observed among hybrids on grain and corn ear yield was due to the timing of male and female flowering and individual weight of the corncob and grain. These results are consistent with those reported elsewhere[12,47], who observed that grain weight depended on the growth and development of the plant and that the grain yield depended on the grain weight and the number of grains per row. Thus, it would be possible that the differences observed in grain yield between sowing seasons and among hybrids were because the plants sown in spring developed greater photosynthetic capacity due to a longer vegetative stage; which consequently results in an increased leaf area index as hypothesized by Reta *et al*[24]. It can infer that increasing the diameter of the corncob and reducing the number of grains affected directly the grain and corn ear yield. Therefore, as previously hypothesized[38] and based on our observations, in order to improve the grain yield, it is necessary to consider, firstly, biomass production rather than grain weight.

Most of the evaluated variables that influence the total production of biomass were influenced by the season, year of sowing and hybrid; therefore, the third hypothesis is rejected. Similar to the previous sections (yield of forage and grain); the organs of the plant evaluated growth and develop better in the spring sowing; consequently, the total biomass production was higher in the spring sowing rather than summer sowing. These results concur with Reta *et al*[24], who observed that the organs of the maize plants sown in spring developed better than the maize plants sown in summer. These results corroborate the observed variation among hybrids in relation to the total biomass production, and are consistent with others[12,38] who reported that the total yield of maize depends on the proper development of each of the plant components.

## Conclusions and implications

The hybrids used in this experiment presented good adaptation to the conditions of the dairy basin of La Laguna; consequently, their forage yield, dry matter production, fiber content, grain yield and biomass production were acceptable. Production of biomass will depend on the proper development of plant organs. External factors affected directly the total yield of maize, regardless of the hybrid used. Therefore, producers in the livestock industry need to consider sowing in spring and use cultivars or hybrids tolerant to drought and extreme temperatures to avoid the negative effect of these conditions on plant growth and development. Moreover, sowing in spring will improve the biomass production and will help producers to realize the full potential of the selected hybrids; consequently, decrease the NDF and ADF of food and increase animal productivity.

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