Impacts of sowing delay on summer corn in a Mediterranean sandy soil: Biomass production, nutrients uptake and nutritive value

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Abstract

Corn is a major forage in intensive dairy systems. In northern Morocco, the production of summer corn after spring corn became a common practice. The aim of this study was to assess the impact of sowing delay on productivity, nutrient uptake, and forage quality of summer corn. An experiment was conducted during the summer of 2019. Four sowing dates (July 14, July 24, August 3, and August 13) were tested in a randomized complete block design with five replications. All the sowing dates were supplied with the same amount of nutrients. At harvest, the sowing delay induced a significant decline in biomass production for August 13 (-46%) compared to July 24. In addition, the highest stem height and stem diameter were recorded for the July 14 and July 24 sowing dates. The plant nutrients contents were similar for all the sowing dates. However, N, K, Mg, Fe, Mn, and Zn uptake were significantly affected by the sowing dates. The lowest amount of N, K, Mg, Fe, Mn, and Zn uptake were recorded for the August 13 sowing date. Late summer sown corn appeared to use N and K less efficiently than earlier summer corn. This study can help producers to determine the appropriate sowing window for summer silage corn in the southern Mediterranean region, especially in Loukkos region of Morocco.

Keywords: N, P, K, nutrient use efficiency, biomass yield, sowing date, forage quality

INTRODUCTION

Corn is one of the most-produced cereal crops in the world (Wrigley, 2017). It is a major forage for ruminants essentially due to its high dry matter yields and low production cost (Allen *et al.*, 2003). The sowing date is a key factor for corn productivity (Kotch *et al.*, 1995). Mostly, corn-sowing time determines the possibility of producing additional crops within the year. Indeed, it is essential for multiple-annual cropping systems (Maresma *et al.*, 2021). The importance of corn sowing date was related to its biomass production (Djaman *et al.*, 2022; Long *et al.*, 2017; Zhang *et al.*, 2019). The negative impacts of corn planting delay have been reported in the literature (Abdala *et al.*, 2018; Maresma *et al.*, 2019; Tsimba *et al.*, 2013). Important delays in sowing significantly reduced grain yield by 74% (Khan *et al.*, 2002). Shrestha *et al.* (2018) reported a decrease in both grain number per ear and 1000-kernel weight. In contrast, Zhang *et al.* (2019) reported a higher 1000-kernel weight with late sowing dates than with early sowing dates.

Besides biomass production and its allocation, forage quality is a major component of forage production. Delaying corn sowing has been reported to induce a decrease in forage quality (Opsi *et al.*, 2013). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were among the main quality parameters affected by late sowing dates of corn. Shirkhani *et al.* (2012) reported an increased NDF and ADL contents in early July corn compared to mid-June. Elsewhere, early planted corn resulted in the highest uptake of nutrient elements, especially nitrogen, potassium, and potassium (Banotra *et al.*, 2017). Precisely, late-sown corn resulted in low agronomic efficiency of nitrogen (Kuneski *et al.*, 2020) compared to early-sown corn. Under Mediterranean irrigated conditions, spring corn should be planted around mid-May for double annual forage cropping systems (Maresma *et al.*, 2019). However, no recommendations have been reported for summer corn following a spring forage crop. In the sandy soil of the Loukkos area (Northern Morocco), silage corn is usually produced twice a year; from March to July and from July to November (Aït Houssa *et al.*, 2008). Both spring and summer corn are supplied with the same amounts of nutrient elements. However, the authors reported that spring corn yields (around 61 $t.ha^{-1}$ green yield) are higher than the summer ones (around 42 $t.ha^{-1}$ green yield). This study aimed to determine the impacts of sowing delay on biomass production, nutrient uptake, and forage quality of summer corn in this southern Mediterranean region.

MATERIAL AND METHODS

Experimental site

A field experiment was conducted in 2019. The experimental site was located in the Loukkos area (northern Morocco, 35°00'N, 6°12'W, 30 m above sea level). The soil was sandy (86.4% sand) with low organic matter level (1.1%). The other soil properties are reported in Table 1.

Crop management and experimental design

After the harvest of spring silage corn, the land was plowed using a cultivator before sowing the next crop. A subsurface drip irrigation system was installed before the first sowing. The drip lines were buried at 30 cm and were separated by 100 cm. On the drip lines, the emitters were 50 cm apart and had a flow of 1 l h^{-1}. After each sowing, sprinklers were installed to ensure an adequate

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plant emergence. For all the sowing dates, the planting was done manually at a rate of 120 000 seeds ha^{-1}. The row spacing was 70 cm. For each plot, the first sowing line was close to the subsurface drip line. Four sowing dates were evaluated: July 14, July 24, August 3 and August 13. The experimental design was a randomized complete block with five replications. The experimental plots had a size of 56 m^2 (8 m × 7 m). All the plots were maintained free of any crop until the planned sowing date.

The fertilizer rates were 281, 60, and 228 kg ha^{-1} for respectively N, P_2O_5, and K_2O, . Such amounts were applied to avoid nutrient insufficiency and avoid any limiting factor. Ammonium nitrate, diammonium phosphate and potassium sulfate were used as sources of nutrients. 24% of nutrients were applied at sowing and 76% were applied by fertigation using a subsurface drip irrigation system. Regarding micronutrients, 35 kg ha^{-1} of zinc sulfate, 5 kg ha^{-1} manganese sulfate, and 1 kg ha^{-1} copper sulfate were applied. All the sowing dates received the same amounts of nutrients. A mixture of pre-emergence herbicides was used for weed control. Also, Epoxiconazole was used to control fungal disease (*Setosphaeria turcica*). During the growing season (July to November), the average minimum and maximum temperatures were around 15.6°C and 24.0 °C. The rainfall and irrigation amounts were, respectively around 170.2 and 421.5 mm (Figure 1).

Table 1: Soil properties (0-30 cm)

Soil properties	0-20	20-40
Sand (%)	89.8	90.0
Silt (%)	3.5	3.3
Clay (%)	7.2	7.5
pH[a]	7.5	7.6
Cation exchangeable capacity (meq 100 g^{-1})[b]	3.2	2.2
Electrical conductivity (ds m^{-1})[a]	0.25	0.16
Organic matter (%)[c]	1.02	0.50
Total nitrogen (%)[d]	0.06	0.03
Phosphorus (mg kg^{-1})[e]	98.7	57.2
Potassium (mg kg^{-1})[f]	119.5	120.3
Magnesium (mg kg^{-1})[f]	99.6	82.2
Copper (mg kg^{-1})[g]	0.94	0.38
Manganese (mg kg^{-1})[g]	4.23	3.20
Iron (mg kg^{-1})[g]	17.4	11.1
Zinc (mg kg^{-1})[g]	5.12	1.66

[a]Determined in a soil: water ratio of 1/5, [b]Determined using Cobaltihexamine Chloride method, [c]Determined using Walkey-Black method, [d]Kjeldahl extraction method, [e]Olsen extraction method, [f]Ammonium acetate extraction at pH = 7,[g]DTPA extraction at pH = 7.3.

Measurements

Growth parameters and silage yield

Harvest was done at 35% of dry matter content. This dry matter percentage was noted after the plants were harvested. An area of 2.2 m^2 per experimental plot was cut and chopped using a silage harvester, and oven-dried to determine the dry matter weight. For each experimental plot, 10 plants were separated into leaves, stem and ears to determine the biomass allocation. The leaf area was determined using formula (1) (Mokhtarpour *et al.*, 2010).

$$Leaf\ area\ (m^2\ plant^{-1}) = \sum_{i=1}^{n}(l_i * w_i * 0.75) \quad (1)$$

Where l, w, and i are respectively leaf length, leaf greatest width, and leaf number for a given layer.

Forage quality analysis

At harvest, plants samples were cut and chopped to determine forage quality for each experimental plot. Then, the samples were chemically analyzed for mineral matter and fat content. The mineral matter was determined after calcination at 550 °C of the dry sample. The fat content was determined using a Soxhlet extractor. Crude protein, cellulose, starch, dry matter digestibility (DMD), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed using a near-infrared reflectance spectrophotometer (InfraXact, FOSS). Thereafter, the net energy lactation was determine using formula (2) (Harlan *et al.*, 1991).

$$NE_L(Mcal\ kg^{-1}\ DM) = 2.196 - 0.0278 * ADF\ (\%\ DM) \quad (2)$$

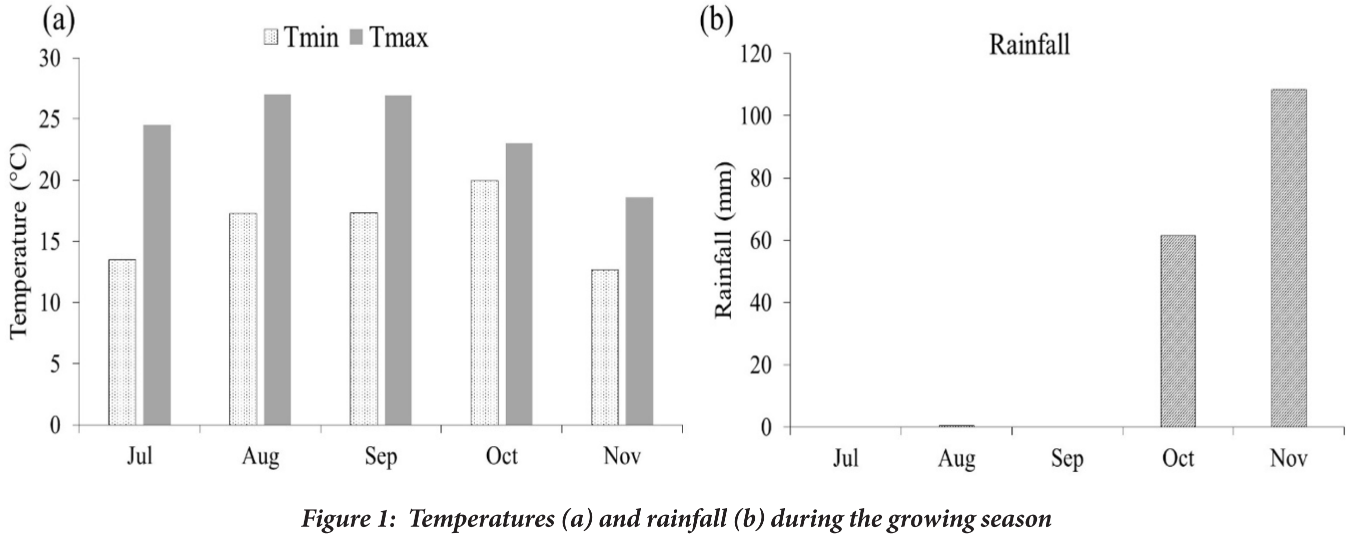

Figure 1: Temperatures (a) and rainfall (b) during the growing season

Forage mineral uptake

The dry matter was shopped to determine the mineral content. A sample of 0.6 g was digested with a mixture of salicylic and sulfuric acids to determine the N, P, K, and Mg concentrations (Walinga *et al.*, 1995a). N and P concentrations were determined using a continuous flow analyzer (Skalar San ++, Skalar, Breda, Netherlands). The K and Mg contents were determined using an atomic absorption spectrophotometer (Varian AA 240, Fast Sequential, air acetylene flame).

In addition, a subsample of 2 g was digested with 20 ml of a tri-acid mixture (350 ml of nitric acid + 40 ml of perchloric acid + 30 ml of sulfuric acid) to determine copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) concentrations (Walinga *et al.*, 1995b). Zn, Fe, Mn, and Cu were analyzed using an atomic absorption spectrophotometer (Varian AA 240 Fast Sequential; air acetylene flame).

The total uptake (for aerial biomass) of each nutrient element was calculated according to formula (3).

$$\textbf{Nutrient uptake (kg ha}^{-1}\textbf{) = Nutrient content (\% dry matter)} \times \textbf{Total aerial biomass (kg ha}^{-1}\textbf{)} \quad (3)$$

The uses efficiency of N, P, and K were determined according to formula (4).

$$\textbf{Nutrient use efficiency (kg kg}^{-1}\textbf{) = Nutrient uptake (kg ha}^{-1}\textbf{)/Nutrient supply (kg ha}^{-1}\textbf{)} \quad (4)$$

Statistical analysis

The experimental data were subjected to analysis of variance (ANOVA). The comparison of means, using the Student-Newman-Keuls test, was carried out at 5 % level of significance. The statistical analyses were performed using the program SPSS (Version 20.0).

RESULTS

Biomass production and growth parameters

At harvest, the produced dry biomass was significantly influenced by the sowing delay (Table 2). The highest dry biomass yield was recorded for the July 24 sowing date (18.7 t ha^{-1}). August 13 sowing date led to a biomass yield decrease of 46% compared to July 24. Similarly, the ear and grains' dry biomass were significantly influenced by the sowing dates (Table 2). The highest ear and kernels dry weights were recorded for the July 24 sowing date with 112.6 and 90.1 g for ear and grains dry biomass, respectively. August 13 sowing date resulted in the lowest ear and grains biomass with 39.8 and 21.6 g for ear and grains, respectively.

Moreover, the stem height was significantly affected by the sowing dates (Table 2). July 14 and 24 sowing dates recorded the highest stem height (228.2 cm). At the August 13 sowing date, the stem height decreased by 25% compared to July and July 24 sowing dates. Similarly, the stem diameter and the leaf area were significantly influenced by the sowing delay (Table 2). The highest stem diameter values were recorded for the July 14 and 24 sowing dates (around 1.7 cm). August 3 and 13 sowing dates recorded the lowest stem diameter values (around 1.5 cm). The leaf area showed a decline of 30% for the August 13 sowing date compared to July 14, July 24, and August 3 sowing dates.

Forage mineral content, nutrient uptake, and uses efficiencies of nutrients

The forage mineral content was similar for all the sowing dates. N, P, K, and Mg levels were, respectively, around 1.5, 0.5, 1.2, and 0.3% (Table 3). As for the micronutrients, Cu, Fe, Mn, and Zn contents were, respectively, around 11.0, 162.1, 15.2, and 50.9 mg kg^{-1} (Table 4).

Table 2: Dry yield, ear and grain biomass, stem high, stem diameter and leaf area at harvest for different sowing dates

Sowing dates	Silage dry biomass* (t ha^{-1})	Ear biomass(g)	Grains biomass (g)	Stem height (cm)	Stem diameter (cm)	Leaf area (m² plant^{-1})
July 14	14.8 ± 3.2 ab	97.5 ± 29.6 b	77.3 ± 25.1 b	230.2 ± 42.3 a	1.7 ± 0.3 a	0.3 ± 0.1 a
July 24	18.7 ± 2.9 a	112.6 ± 41 a	90.1 ± 37.6 a	226.2 ± 27.6 a	1.7 ± 0.3 a	0.3 ± 0.1 a
August 3	14.9 ± 3.4 ab	84.1 ± 31.9 c	62.1 ± 22.3 b	203.9 ± 34.0 b	1.5 ± 0.2 b	0.3 ± 0.2 a
August 13	10.1 ± 2.5 b	39.8 ± 19.9 d	21.6 ± 13.1 c	170.4 ± 26.2 c	1.5 ± 0.3 b	0.2 ± 0.1 b

*Values are mean ± standard deviation. For each column, values with the same letters are not significantly different (n=50). *n=5.*

Table 3: Macronutrients content at harvest for different sowing dates

Sowing dates	N (%)	P (%)	K (%)	Mg (%)
July 14	1.5 ± 0.1 a	0.5 ± 0.1 a	1.2 ± 0.2 a	0.28 ± 0.05 a
July 24	1.5 ± 0.3 a	0.4 ± 0.2 a	1.3 ± 0.4 a	0.23 ± 0.06 a
August 3	1.4 ± 0.1 a	0.4 ± 0.1 a	1.1 ± 0.0 a	0.24 ± 0.03 a
August 13	1.7 ± 0.1 a	0.6 ± 0.1 a	1.0 ± 0.1 a	0.26 ± 0.03 a

Values are mean ± standard deviation. For each column, values with the same letters are not significantly different (n=5).

Table 4: Micronutrients content at harvest for different sowing dates

Sowing dates	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})
July 14	9.7 ± 0.8 a	187.4 ± 47.2 a	17.8 ± 2.4 a	64.1 ± 25.3 a
July 24	10.8 ± 2.9 a	162.7 ± 33.4 a	16.0 ± 3.7 a	57.8 ± 10.8 a
August 3	9.9 ± 1.4 a	136.0 ± 26.4 a	13.9 ± 2.5 a	41.6 ± 7.5 a
August 13	13.4 ± 2.8 a	162.3 ± 21.2 a	13.1 ± 1.8 a	40.3 ± 4.3 a

Values are mean ± standard deviation. For each column, values with the same letters are not significantly different (n=5).

Concerning the forage macronutrient uptake, a significant influence of sowing dates was recorded for N and K. Indeed, the July 24 sown corn absorbed the highest amount of N and K with respectively 286.3 and 250.3 kg ha^{-1} (Table 5). At the August 13 sowing date, N and K uptake decreased respectively by 41 and 59%. The P absorption was not significantly affected by the sowing date (Table 5). The average P uptake was 68.6 kg ha^{-1} for all the sowing dates. Regarding the Mg uptake, it was significantly affected by the sowing dates (Table 5). The highest Mg level was recorded for July 14 and July 24 sown corns (42.4 kg ha^{-1}). At august 13, the Mg uptake decreased by 39%.

The sowing delay induced a decrease of N and K use efficiencies at the August 13 sowing date (Table 6). Compared to the July 24 sowing date, the decline rates were respectively 41 and 59% for N and K. In contrast, no significant difference was noticed for the phosphorus use efficiency. The average P use efficiency was 1.1 kg kg^{-1}.

Fe and Mn uptakes were significantly affected by the sowing dates (Table 7). The highest Fe and Mn absorption were recorded for the July 24 sown corn with respectively 3.1 and 0.295 kg ha^{-1}. At the August 13 sowing date, Fe and Mn uptake showed a decrease of 47 and 56%, respectively. The Cu absorption was not significantly impacted by the sowing dates (Table 7). The average Cu uptake was 0.160 kg ha^{-1} for all the sowing dates. However, the Zn uptake was significantly influenced by the sowing dates (Table 7). The highest Zn level was recorded for July 14 and July 24 sown corns with 0.99 kg ha^{-1}. At the August 3 and August 13 sowing dates, the Zn uptake decreased by 49%.

Forage quality

The forage nutritive value was not influenced by the sowing delay (Figure 2). The net energy for lactation was similar for all the sowing dates (around 6.5 MJ kg^{-1} DM). The mineral matter, fat and crude protein contents were respectively around 3.8, 1.6 and 8.1% of dry matter (Figure 2). Cellulose and starch contents in the forage were, respectively, 19.8 and 30.5% for all the sowing dates. The dry matter digestibility was around 64.2%. The neutral detergent fiber (NDF), the acid detergent fiber (ADF), and the acid detergent lignin (ADL) were, respectively, around 42.3, 23.2, and 2.4% (Figure 2).

DISCUSSION

The production of summer silage corn after spring silage corn has become a common practice in Northern Morocco (Aït Houssa *et al.*, 2008). Indeed, the intensive forage cropping systems based on a succession of spring and summer corn after a winter crop (oat or pea/triticale association) ensure a higher biomass production with maximum net energy for lactation and total crude protein (Hassane Sidikou *et al.*, 2023). However, an important sowing delay (20-30 days) of summer corn can be observed according to the sowing/harvest time of spring corn. The results of this study showed a 46% of dry biomass yield decrease for the late summer corn. The biomass decline at late sowing dates was related to the ear biomass decrease, particularly the grains' dry biomass (Table 2). Indeed, the produced grains' biomass decreased by 76% for the August 13 sowing date compared to July 24. This kernel biomass decrease was mainly attributed to the reduction of the kernel num-

Table 5: Macronutrients uptake at harvest for different sowing dates

Sowing dates	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Mg (kg ha^{-1})
July 14	218.6 ± 57.7 ab	73.4 ± 13.1 a	181.6 ± 42.9 ab	41.2 ± 6.8 a
July 24	286.3 ± 81.6 a	79.1 ± 17.9 a	250.3 ± 105.6 a	43.6 ± 14.4 a
August 3	215.8 ± 58.5 ab	63.8 ± 19.0 a	165.3 ± 37.4 ab	35.5 ± 10.4 ab
August 13	170.0 ± 40.3 b	58.1 ± 19.8 a	102.1 ± 26.7 b	25.9 ± 4.3 b

Values are mean ± standard deviation. For each column, values with the same letters are not significantly different (n=5).

Table 6: Use efficiencies of N, P, and K for different sowing dates

Sowing dates	N (kg kg^{-1})	P (kg kg^{-1})	K (kg kg^{-1})
July 14	0.8 ± 0.2 ab	1.2 ± 0.2 a	0.8 ± 0.2 ab
July 24	1.0 ± 0.3 a	1.3 ± 0.3 a	1.1 ± 0.5 a
August 3	0.8 ± 0.2 ab	1.1 ± 0.3 a	0.7 ± 0.2 ab
August 13	0.6 ± 0.1 b	1.0 ± 0.3 a	0.4 ± 0.1 b

Values are mean ± standard deviation. For each column, values with the same letters are not significantly different (n=5).

Table 7: Micronutrients uptake at harvest for different sowing dates

Sowing dates	Cu (kg ha^{-1})	Fe (kg ha^{-1})	Mn (kg ha^{-1})	Zn (kg ha^{-1})
July 14	0.146 ± 0.04 a	2.7 ± 0.6 ab	0.260 ± 0.04 ab	0.90 ± 0.3 a
July 24	0.206 ± 0.08 a	3.1 ± 0.9 a	0.295 ± 0.06 a	1.07 ± 0.2 a
August 3	0.150 ± 0.05 a	2.1 ± 0.7 bc	0.204 ± 0.04 b	0.61 ± 0.1 b
August 13	0.136 ± 0.04 a	1.6 ± 0.4 c	0.129 ± 0.02 c	0.40 ± 0.1 b

Values are mean ± standard deviation. For each column, values with the same letters are not significantly different (n=5).

ber per ear (Shrestha *et al.*, 2018). The negative impact of sowing delay on grain yield was reported by many authors (Zhai *et al.*, 2022; Bonelli *et al.*, 2016; Khan *et al.*, 2002; Rahmani *et al.*, 2016). The grain yield of late-sowing dates was mainly limited by the photosynthetic source capacity (Bonelli *et al.*, 2016). Variations in grain yield were closely related to dry matter accumulation during the post-silking period. In addition, lower growth duration, lower temperatures and solar radiation in the late season limited grain filling (Rahmani *et al.*, 2016), resulting in low grain biomass.

Furthermore, the sowing delay induced a decrease in nutrient uptake levels. Although all the sowing dates were supplied with the same amount of nutrients, August 13 sown corn resulted in the highest decrease of macronutrients (-46%) and micronutrients (-51%) uptake compared to the highest values recorded. In addition, nutrients seemed to be less efficiently used by late summer sown corn (Table 6), confirming previous findings (Kuneski *et al.*, 2020). Such results emphasize the importance of further experiments to reduce the fertilization rates through the summer season, since late sowing dates failed to assimilate a large amount of nutrients as for the July sowing dates. This reduction is necessary in the view of the current situation of increasing fertilizer prices, not to mention that the sandy soil has low nutrient retention capacity (CEC=3.2 meq 100 g^{-1}, clay=3.2%). The negative impact of sowing delay on corn macronutrient uptake has been reported (Banotra *et al.*, 2017). This nutrient uptake decline was mainly attributed to the biomass yield (Table 2) since no significant difference was recorded for all the nutrients content in the forage (Table 3, Table 4 and Table 5). Further research is to be conducted to determine the appropriate amount of nutrients supply, particularly a multiyear experiment combining sowing dates and fertilization rates.

Regarding the forage nutritive value, no significant effect of the sowing dates was noticed for all the tested quality parameters. These results contrast with those reported by Shirkhani *et al.*, (2012). In fact, these authors reported a significant effect of sowing dates on NDF and ADF for a maximum plant density of 100 000 plants ha^{-1}. From these results, the nutritive value of corn, sown at a density of 120,000 plants ha^{-1}, does not seem to be affected by the sowing delay under northern Moroccan conditions.

CONCLUSION

Summer corn production became a necessary practice for intensive dairy systems in the southern Mediterranean region. The impact of sowing delay on the productivity, nutrient status, and forage quality of summer corn in northern Morocco was evaluated. The results showed a significant decline in growth parameters and biomass production when sowing is delayed. In addition, late-sown silage corn failed to uptake up the same amount of nutrients as the early summer season sowing dates, even if the plant mineral content was not affected by the sowing delay. Indeed, August 13 sown corn resulted in the lowest uptake of N (-41%), K (-59%), Mg (-39%), Fe (-47%), Mn (-56%), and Zn (-49%) compared to the highest values recorded. Such results emphasize the necessity to reduce the fertilization rates for summer corn production.

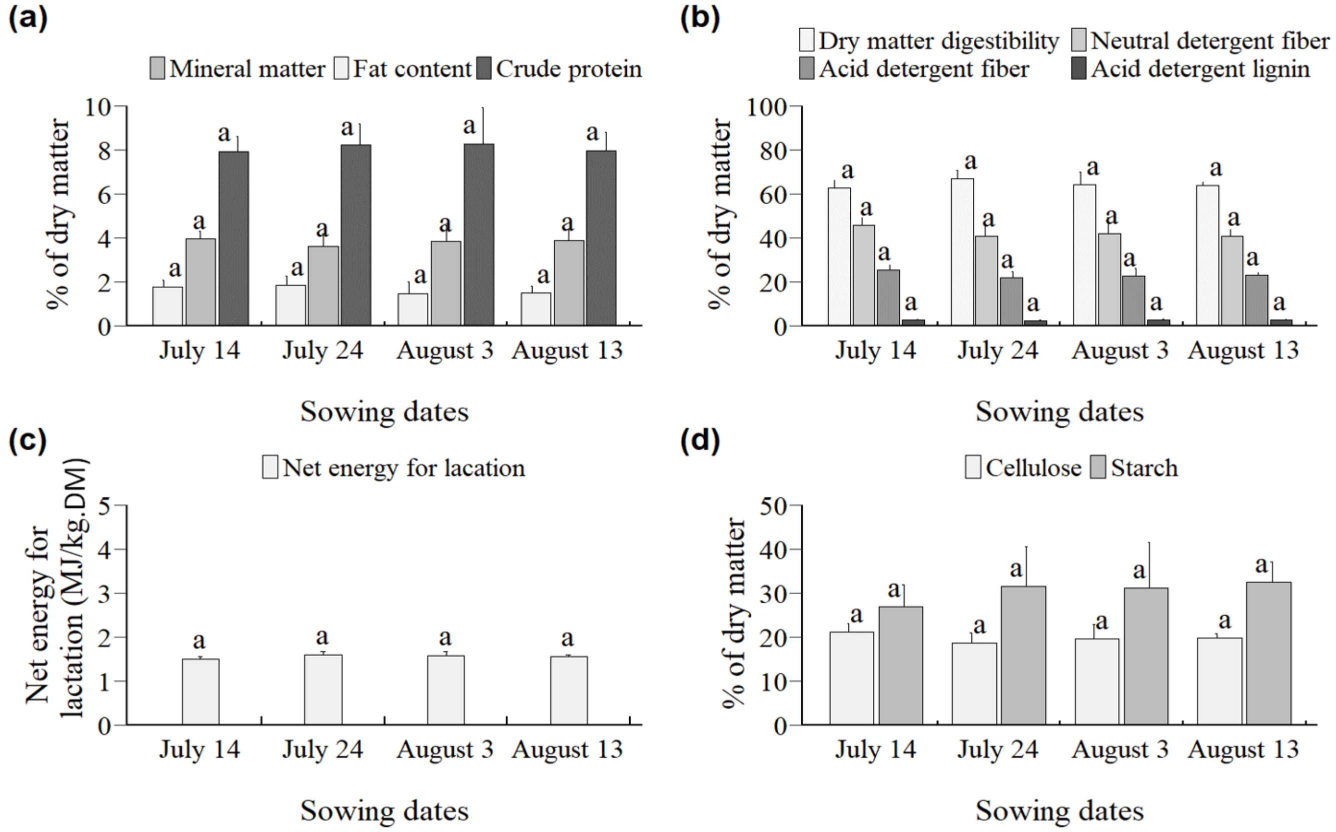

Figure 2: Forage quality parameters for different sowing dates. For each parameter, values with the same letters are not significantly different. Vertical bars are standard deviation (n=5)

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