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# Effect of Irrigation on Corn Plant Dry Matter Yield, Morphological Components and Ruminal Degradability of Leaves and Stems

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**Abstract:** Plant weight, morphological components and *in situ* Dry Matter (DM) degradability of leaves, stems and tissues of stems (rind and pith tissues) were investigated in a rain fed or irrigated corn crop at the time of ensiling. The crop was sown at a density of 8 plants $m^{-2}$ in a randomized complete block design with three replications. Plants were harvested at half milk line and weights of ears, grains, husks, cobs, stems, leaves, rind and pith tissues (DM base) were determined in four plants/plot. Ground (2 mm) samples (5 g DM) of leaves, stems, rind and pith tissues were incubated (nylon bags of 10×20 cm) in three ruminal fistulated heifers for periods of 0, 12 and 24 h. Data of the three heifers were averages and the intercept (soluble fraction) and slope (degradation rate) of each fraction was estimated by linear regression. Plant and *in situ* data were analyzed as a completely randomized block design with three replications. Irrigation increased plant DM yield (259 to 350 g) and grain production (110 to 158 g) per plant. However, it did not affect the content of grain in the plant (43%) or the content of leaves (38%) and stems (32%) in the stover. Neither the 24 h *in situ* degradability of leaves (44%) and stems (25%) was affected. It was concluded that irrigation increased DM yield by approximately 35%, without affecting the stover morphological composition, the grain to stover ratio and the *in situ* DM degradability of leaves, stems and stem tissues.

**Key words:** Corn, irrigation, plant morphology, stover, ruminal degradability

## INTRODUCTION

Corn is grown as a silage crop throughout much of the world because of its high dry matter yield and good feed quality for livestock. In many regions of the world grain production can be severely damaged when moisture is limited and between tasseling and grain filling. Irrigation has shown to increase grain production for approximately 40% (Di Marco *et al*., 2002) but it is expensive and its effect on stover quality has not been determined.

Stover digestibility is presently considered a major objective in many research projects and because in cooler regions of the world it seems to be as important as grain content (Deinum, 1988; Toleram *et al*., 1998). Nonetheless, the fact that in sunny warm climates the quality of silages is determined by the content of grain in the plant has led to the generalized concept that the best hybrids for grain production are also the most suitable for ensiling (Allen *et al*., 2003). For this reason factors that might be beneficial for stover digestibility have been poorly investigated.

Stover digestibility could be affected by growing environments, locations, hybrid characteristics and management practices (Allen *et al*., 2003; Given and Deaville, 2001; Irlbeck *et al*., 1993). However, the information and is still scarce to identify the management practices that might improve stover digestibility. The stover is a dynamic feedstuff comprised by variable amounts of leaves and stems, which are plant components of different and variable ruminal degradability (Verbic *et al*., 1995). The stems are the less degradable part of the plant due to their rigid structure (Jung *et al*., 1998), in which the parenchyma of the rind tissues accounts for the grater part of cell wall accumulation and lignification (Jung and Casler, 2006). Nonetheless, under certain growing conditions the stems can be as degradable as leaves (Verbic *et al*., 1995), which suggest that the content of pith tissues and/or its degradability could be increased. This experiment was carried out with the objective to investigate the effect of irrigation on corn plant yield and morphology, as well as on the *in situ* degradability of leaves and stems. In addition, the content and degradability of the rind and pith tissues of the stems were studied.

## MATERIALS AND METHODS

A corn hybrid of relative maturity of 110 days (Dekalb 615) was sown in mid October 2001 at Balcarce, Argentina (37° 45′ S, 58° 18′ W) in plots of four rows of 14 m

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long separated by 0.7 m (39 $m^2$) at a sowing density of 8 plants $m^{-2}$. The experimental design was a completely randomized block with two treatments (rain fed and irrigation) and three replications. The rainfall during the crop cycle (October-March) was 560 mm. Half of the crop received an additional irrigation from tasseling to grain filling andto maintain the plant water availability, in the first meter of soil, above 60% of field capacity (approximately 130 mm). All plots were fertilized at sowing with 30 kg P $ha^{-1}$ and with 140 kg N $ha^{-1}$ at crop stage V5-V6, according to the morphological scale of (Ritchie *et al*., 1996). The crop was maintained free of weeds by manual control when necessary. No visual damages from insects and diseases were observed.

Twelve plants per treatment (four per plot) were hand-cut at 15 cm above ground (March 16, 2002) at kernel maturity stage of half milk line (R5 (Ritchie *et al*., 1996). Fresh plants were dissected in ears, grains, husks, cobs, stems, leaves (including the sheaths). The lower stem five basal internodes were further separated in rind and pith tissues. Each fraction was fresh weighed and dried (60°C) for Dry Matter (DM) weight determinations. The harvest index was calculated as the ratio DM weight grain/DM whole plant weight.

For the *in situ* study, leaves, stems, rind and pith tissues were ground to pass a 2 mm mesh and incubated in three ruminal fistulated heifers of 400±12 kg of body weight. Animals were kept on individual pens during 15 days with fresh water always available and fed twice a day to reach maintenance of body weight (AFRC, 1993) with a medium quality alfalfa hay (*in vitro* digestibility = 60%, neutral detergent fiber = 56% and crude protein = 19%). Previous to incubations animals had an adaptation period of 10 days. Duplicate samples of approximately 5 g DM were placed in dacron bags of 10 x 20 cm and 50 μ pore size (Ankom Company, Fairport, NY), soaked for 15 min at 39°C and then incubated in the rumen for periods 0, 12 and 24 h. After removal from the rumen, bags were hand washed with tap water until it run clear, dried at 60°C for 48 h and weighted.

The intercept (soluble fraction) and slope (degradation rate) of leaves, stems, rind and pith tissues were estimated by linear regression using the average of the three heifers as one observation. All data (plant and *in situ* data) were analyzed as a completely randomized block design with three replications with the general linear model procedures of SAS (1998) and mean differences were compared by the Tukey and Krammer test ($p<0.05$).

## RESULTS AND DISCUSSION

As shown in Table 1, there was an important effect of the additional irrigation on grain yield per plant, which increased ($p<0.05$) by 43% (110 to 158 g). This represents an increase in grain production from 8.8 to 12.6 Tn $ha^{-1}$, which is the expected effect of an irrigation of 150 mm of water in the area (USDA, 2006). It is important to note that the effect of irrigation on grain production was through the increase in plant DM yield, which increased 35% (259 to 350 g). For this reason the proportion of grain in the plant (harvest index) was similar between the rain fed and the irrigated crop, in average 43.8%. This association between a parallel increase in plant and grain weight has been reported by Allen *et al*. (2003), who stated that corn hybrids selected for high grain yielding increased total forage yield without changing the content of grain in the plant.

The harvest index reported in our experiment is in agreement with data reported by other researchers in our area (Arias *et al*., 2003; Cirilo and Andrade, 1994) and in other countries (Cox *et al*., 1994; Keuhn *et al*., 1990; Tolera *et al*., 1998; Verbic *et al*., 1995). It is worth noting that the grain to stover ratio, which determines the content of starch (grain) and fiber (stover) in the silage, was not affected ($p>0.05$) by irrigation (0.75:1 vs. 0.82:1, Table 2) because grain and stover production increased in similar trend. In other words, in spite of the 35% increase in crop tonnage for ensiling the plant was comprised by a similar grain to stover ratio.

In Table 2 is shown that irrigation did not affect either the proportion of leaves, stems and husks, however cob weight was increased ($p<0.05$) from 16 to 19%. The average morphological composition of the stover was

Table 1: Dry matter weight of whole plant, ear, grain and stover, and harvest index of rain fed and irrigated corn plants

| Parameters | Rain fed | Irrigated | EEM | Differences |
|---|---|---|---|---|
| Plant weight (g) | 258.6 | 349.9 | 17.80 | * |
| Ear weight (g) | 152.5 | 219.3 | 12.04 | * |
| Grain weight (g) | 110.2 | 157.9 | 9.21 | * |
| Stover weight (g) | 148.4 | 192.0 | 9.52 | * |
| Harvest index (%) | 42.3 | 45.3 | 1.30 | NS |

*p<0.05; NS = Non significant (p>0.05)

Table 2: Morphological composition of stover of rain fed and irrigated corn plants

| Parameters | Rain fed | Irrigated | EEM | Differences |
|---|---|---|---|---|
| Leaves (% stover, DM basis) | 39.5 | 36.5 | 0.98 | NS |
| Stems (% stover, DM basis) | 32.0 | 31.5 | 0.95 | NS |
| Rind tissues (% stem, DM basis) | 72.3 | 74.1 | 0.95 | NS |
| Pith tissues (% stem, DM basis) | 27.7 | 25.9 | 0.60 | NS |
| Husk (% stover, DM basis) | 12.4 | 12.9 | 1.07 | NS |
| Cobs (% stover, DM basis) | 16.1 | 19.1 | 0.49 | * NS |
| Ear/stover ratio | 1.03:1 | 1.14:1 | 0.15 | NS |
| Grain/stover ratio | 0.75:1 | 0.82:1 | 0.11 | NS |
| Grain/stem ratio | 3.13:1 | 3.17:1 | 0.25 | NS |
| Leaf/stem ratio | 1.23:1 | 1.15:1 | 0.40 | NS |

*p<0.05; NS= Non significant (p>0.05)

Table 3: *In situ* DM degradability of leaves, stems and rind and pith tissues of stems of rain fed and irrigated corn plants

| Component | Treatment | Soluble fraction (intercept) (%) | Degradability rate of insoluble fraction (% per h) | $R^2$ | Degradability at 24 h (%) |
|---|---|---|---|---|---|
| Leaves | Rain fed | 12.4±3.5 | 1.2±0.2 | 0.80 | 42.6±4.8 |
| | Irrigated | 18.3±3.4 | 1.1±0.2 | 0.78 | 45.1±4.8 |
| | Average | 15.4±2.5b | 1.2±0.2a | 0.77 | 43.9±4.8a |
| Stems | Rain fed | 14.2±2.4 | 0.4±0.2 | 0.65 | 24.8±3.0 |
| | Irrigated | 9.9±2.0 | 0.5±0.1 | 0.70 | 25.6±2.6 |
| | Average | 12.0±1.6b | 0.5±0.1b | 0.68 | 25.2±2.8b |
| Rind tissues | Rain fed | 13.6±1.4 | 0.4±0.1 | 0.77 | 24.8±1.4 |
| | Irrigated | 9.9±2.2 | 0.5±0.1 | 0.71 | 23.6±2.6 |
| | Average | 11.8±1.3b | 0.5±0.1b | 0.69 | 24.2±2.1b |
| Pith tissues | Rain fed | 29.0±2.6 | 0.9±0.2 | 0.79 | 49.6±3.6 |
| | Irrigated | 25.9±5.1 | 1.0±0.3 | 0.67 | 48.7±7.3 |
| | Average | 27.5±2.7a | 0.9±0.2a | 0.64 | 49.1±5.5a |

a, b: Average means with similar letter did not differ between fractions (p>0.05)

38% leaves, 32% stems and 13% husks. The 19% increase in cob content might be of minor importance in stover quality, since no affected of irrigation was found on the ear/stover, grain/stover or grain/stem ratios.

The stover presented an average leaf/stem ratio of 1.2: 1, which is higher than the observed in other experiments. Verbiè *et al.* (1995) reported variations in this ratio in eight hybrids from 0.6:1 to 0.9:1 and Arias *et al.* (2003) observed a decrease of this ratio with the advance of maturity from 1.0: 1 in stage R3 to 0.8: 1 in R5 in Ritchie's scaleRitchie *et al.* (1996). Important is to note that stems were comprised by approximately 73% of rind tissues, which implies that approximately 25% of the stover weight consist of these kind of woody tissues that provide the rigid structure of stems that is required to be resistant to environmental factors and pests (Jung *et al.*, 1998).

There was no affect of irrigation on the *in situ* DM degradability parameters for leaves, stems and tissues of the stem, as shown in Table 3. Degradability at 24 h (D-24) of leaves (43.9%) and pith tissues (49.1%) was not different and nearly doubled that of stems and rind tissues, which did not differ between them (average 25%). Important is to quote that these low values of D-24 can not be interpreted as a failure of the *in situ* technique, since in a previous experiment the D-24 values were in range with *in vivo* data (Di-Marco *et al.*, 2005, 2002).

Although pith tissues and leaves had similar degradability at 24 h, they showed different pattern of degradation. Pith tissues presented a higher soluble fraction (27.5 vs. 15.4%), which is rapidly and completely degraded in the rumen (Jhonson *et al.*, 1999), but an insoluble fraction with lower rate of degradation than leaves (0.9 vs. 1.2% $h^{-1}$). Degradability of leaves and stems were in the range with data observed in our area (Arias *et al.*, 2003). Degradability of leaves was also in agreement with data of (Verbiè *et al.*, 1995) but the stem degradability was lower. Differences can be explained by the lower soluble fraction of stems in our experiment, which was 12% and in Verbiè's experiment stems presented 28% of soluble fraction. The lower soluble fraction observed in our experimental condition could be attributed to a limitation in solar radiation (Cirilo and Andrade, 1994). Allen *et al.* (2003) pointed out that limitation in photosynthetic production in cooler regions, such as our area and the northern Europe, induce the mobilization and translocation of nonstructural carbohydrates from the stems to the developing ear. This depresses the content of soluble carbohydrates in stem and, consequently, its digestibility.

The rate of DM degradation of the Insoluble but Degradable Fraction (IDF), which includes the structural components of t he cell wall, was not affected (p>0,05) by irrigation. All plant fractions showed a lineal trend of ruminal degradation during the first 24 h ($R^2$: 0.65-0.80). The rate of degradation of the IDF of leaves (1.2% $h^{-1}$) and pith tissues (0.95 $h^{-1}$) was not different (p>0.05). This rate was lower in stem and rind tissues (0.5% $h^{-1}$), which did not differ (p>0.05) between them. These degradation rates show that the structural components of leaves and stems are poorly degraded in the rumen, in spite that leaves were twice more degradable than stems. The IDF of leaves provided in 24 h of ruminal digestion approximately 30% of degradable substrate and that of stem only 12%. The contribution of this degradable substrate to the 24 h DM degradability was 60% in leaves and 50% in stems, being the difference the contribution of the soluble fraction, which accounted for 40% in leaves and 50% in stems.

## CONCLUSIONS

Under the condition of the present experiment irrigation increase plant dry matter weight by 35% and grain production per plant by 43%, but it did not improve plant quality. Moreover, the content of grain in the plant (~44% on average), the leaves/stems stover ratio (1.2: 1) and the *in situ* DM degradability at 24 h of leaves (~44%)

and stems (~25%) were not affected by irrigation. Neither were affected the proportion and degradability of rind and pith tissues of the stem. Pith tissues were as degradable as leaves, but rind tissues were poorly degraded *in situ* (24%). The high contribution of this tissues to the stem weight (~73%) elucidates the low degradability of stems.

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