Investigation note

# Yield of oat forage Chihuahua variety

Eliseo Sosa-Montes[1]
Sergio Iban Mendoza Pedroza[2§]
José Isidro Alejos de la Fuente[1]
Jorge Armando Villarreal González[3]
Dennise Brizeida Velasco Estrada[1]
Estefany Rodríguez Rosales[1]

[1]Chapingo Autonomous University-Zootechnics Department. Mexico-Texcoco Highway km 38.5, Chapingo, State of Mexico. CP. 56230. Tel. 595 9521500. (eliseososa@yahoo.com.mx; alejos.jose@colpos.mx; denniise.denniise@gmail.com; fannyrdz25@gmail.com). [2]Postgraduate College-Montecillo *Campus*. Mexico-Texcoco highway km 36.5, Montecillo, Texcoco, State of Mexico. CP. 56230. Tel. 595 9520200. [3]Benemérita Autonomous University of Puebla-Faculty of veterinary medicine and zootechnics. Tecamachalco-Cañada Morelos highway km 7.5, Tacamachalco, Puebla. CP. 75460. Tel. 249 42220178. (villagon7@gmail.com).

[§]Corresponding author: sergiomp@colpos.mx.

## Abstract

Due to its importance as forage in Mexico and to know the dry matter yield (DM) and its morphological components, the aerial part of *Avena sativa* L., variety Chihuahua, was studied. The dependent variables DM, yield of DM (YDM), intercepted radiation (IR) were evaluated; yields of leaf (L), stem (S), panicle (P), dead material (MM) and weeds (W), and leaf/stem ratio (L/S). Harvests were made every 15 days of age, from 30 days to 150 days. This research was carried out in the 'Predio Nuevo' experimental field of the College of Postgraduates, Montecillo, Texcoco, State of Mexico, August 2018 to January 2019. The experimental units were small areas limited by a 0.25 $m^2$ table in each plot, for each age, with three repetitions. All the relationships between dependent variables and age were increasing or decreasing sigmoids. The maximum YDM was reached after 120 days: 5 355 kg $ha^{-1}$. Yields for this age were: L (776 kg $ha^{-1}$), S (2 225 kg $ha^{-1}$), P (1 790 kg $ha^{-1}$), MM (304 kg $ha^{-1}$) and W (259 kg $ha^{-1}$). The intersection of L and S was considered the point of best yield quality (82.5 days): 4340 kg $ha^{-1}$. The yields at this point were: L (1 607 kg $ha^{-1}$), S (1 658 kg $ha^{-1}$), P (572 kg $ha^{-1}$), MM (200 kg $ha^{-1}$) and W (303 kg $ha^{-1}$). In conclusion, the harvest age to maximize the yield of the aerial part and the grain was 120 days and to obtain better quality it was 82.5 days.

**Keywords:** *Avena sativa* L., intercepted radiation, morphological composition.

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The lack of forage during the winter constitutes one of the most severe problems for milk and meat producers with a grazing production system. The forage of *Avena sativa* L. has a good yield and nutritional value (Mamani and Cotacallapa, 2018), and is used as a winter crop (Zartash *et al*., 2018).

The cultivation of oats (*Avena sativa* L.), has great importance in Mexico, since it is a key input for the production of balanced feed for livestock use, which, together with its wide range of adaptation, both in high, cold areas and rainy, as in semi-arid environments; places it as a strategic crop. According to SIAP data, the area sown with forage oats in Mexico is 124 741 ha, obtaining a production of 3 103 472 t, with an average yield of 24.9 t ha$^{-1}$ in fresh (SIAP, 2018).

As forage, oats have high digestibility, a high amount of metabolizable energy and their fiber has better qualities than other small grain cereals; while the grain has a high quantity and quality of proteins, carbohydrates, minerals, fats and vitamin B (INFOAGRO, 2010).

From 1961 to date, the National Institute for Forestry, Agriculture and Livestock Research (INIFAP) has released 21 varieties of oats and published information regarding their genetic origin and vegetative characteristics, their adaptation to different environments, and the development of short-cycle varieties. (90 days) with good forage and grain yield, and with tolerance to stem rust (*Puccinia graminis* f. Sp.) (Espitia *et al*., 2007).

Oats are used at any stage of growth for animal consumption, from sprouts in the feeding of minor species, to the milky-mass state of grain. This brings with it the need to know the dry matter production capacity of the crop, to determine the optimal cutting moment that allows increasing its profitability (Espitia *et al*., 2007).

The description of the growth of a plant, or of a crop, throughout its life or production cycle, as well as the evaluation of treatments capable of modifying the biomass accumulation of a vegetable require objective indicators that can be statistically validated. Growth analysis techniques are useful tools for these purposes. They can be applied in multiple situations, but their use in intensive cultivation presents particular aspects to be taken into account, about which the available information is relatively scarce and dispersed (Di Benedetto and Tognetti, 2016).

**Location and date**

The investigation was carried out from August 24, 2018 to January 21, 2019, in the Experimental Field called ‘Predio Nuevo’ of the College of Postgraduates, Montecillo, Texcoco, State of Mexico, located at 19° 29' north latitude, 98° 53’ west longitude and 2 240 masl. The climate of the place is temperate sub-humid, the driest of the sub-humid, with an average annual rainfall of 636.5 mm, rainfall regime in summer (June to October) and an average annual temperature of 15.2 °C (García, 2004). The soil in the area is sandy loam and slightly alkaline, pH 7.8, with 2.4 g (100 g)$^{-1}$ of organic matter (Wilson *et al*., 2018).

### Treatments and experimental unit

The meadows were established in August 2018, planting was done broadcast. There was no fertilization and in the dry season, irrigations to field capacity were provided every two weeks.

The treatments were randomly distributed in three experimental plots, according to a completely randomized block design with three replications. The experimental units were small areas limited by a 0.25 $m^2$ table in each plot, for each age. The first cut was at the age of 30 days and subsequently, the cuts were made every 15 days, until reaching the age of 150 days.

### Yield of dry matter, intercepted radiation and dry matter of the plant

To obtain the dry matter yield (YDM), aerial part, of each plot, in each age, two fixed tables of 0.25 $m^2$ were randomly established in each experimental unit and the forage was harvested at ground level. The forage from each box was deposited in labeled paper bags, washed, placed in a forced air oven, at 55 °C for 72 h and the dry weight was recorded.

For intercepted radiation (IR), a linear sensor was used, which was placed horizontally above the plant canopy, facing east-west, and the incident light outside the canopy was recorded, in photons, to which it was assigned a value of 100. Immediately thereafter, the sensor was placed under the canopy in the same orientation and the incidence of light subtracted from 100 recorded as photons of intercepted light was recorded. The IR was expressed in moles of intercepted photons (100 moles of incident photons)$^{-1}$. The DM of the aerial part was expressed in g (100 g) $^{-1}$. Both L/S, IR and DM were plotted against the age of the plant in days.

### Botanical and morphological composition (yield components) and leaf/stem ratio

At each age, from the samples of forage harvested to determine the yield, a subsample of approximately 20 g kg$^{-1}$ was taken. Each subsample was separated into the species of interest (oats) and unwanted (weeds) to determine the botanical composition. The weight of the species of interest and weeds (W) was equal to the YDM in kg ha$^{-1}$.

The oat plant was separated into its morphological components (leaves, stems, dead material and panicle), to know all the components of the yield. These components were dried in a forced air stove at 55 °C for 72 h and their dry weight was determined.

Leaf, stem, dead material and panicle yields in kg ha$^{-1}$ were named L, S, DM and P, respectively. Their sum plus W, at each age, was almost equal to the YDM mentioned above. Both YDM, L, S, DM and P, as well as W, all of them in kg ha$^{-1}$, were plotted against the age of the plant in days. The ratio of the L/S yields was considered the leaf/stem ratio and was also plotted against the age of the plant in days.

## Climatological data

The maximum monthly temperature ranged from 22 °C to 27 °C, while the minimum monthly temperature ranged from 2 °C to 14 °C. The highest temperatures occurred in the month of February, outside the experimental period, and were higher than 27 °C. The lowest temperatures, of 2 °C, were recorded in December and January. Accumulated precipitation from August 2018 to January 2019 was 437.23 mm, of which 326.33 mm occurred in two months, August and September 2018 with 191 mm and 135.33 mm, respectively.

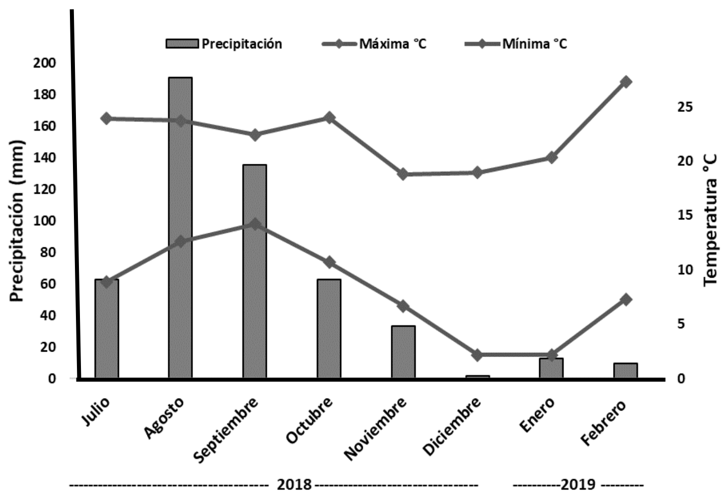


**Figure 1. Average monthly, maximum and minimum temperatures and accumulated precipitation, which includes the study period (July 2018-February 2019).** The bars indicate precipitation and the lines indicate temperatures. The horizontal axis is the same for all three variables.

## Statistical analysis

An analysis of variance was performed with the GLM procedure of the statistical program Statistical Analysis System (SAS, 1999), under a randomized complete block design with three replications. The comparison of means of each dependent variable with advancing age was performed using the Tukey test ($p< 0.05$). Logistic regressions between dependent variables and age in days were performed using the Statistical Package for the Social Sciences program (SPSS, 2011).

## Yield of dry matter, intercepted radiation and dry matter of the plant

Figure 2 shows the dry matter yield (YDM), aerial part, in kg ha$^{-1}$, at different plant ages. A progressive increase in YDM was observed as age advanced. Also shown in this figure are the intercepted radiation (IR) in moles of intercepted photons (100 moles of incident photons)$^{-1}$ and the dry matter (DM) of the aerial part in g (100 g)$^{-1}$. The three variables were increasing logistic functions, dependent on the age of the plant. The logistic coefficients of these three variables for age were different from zero ($p< 0.05$).

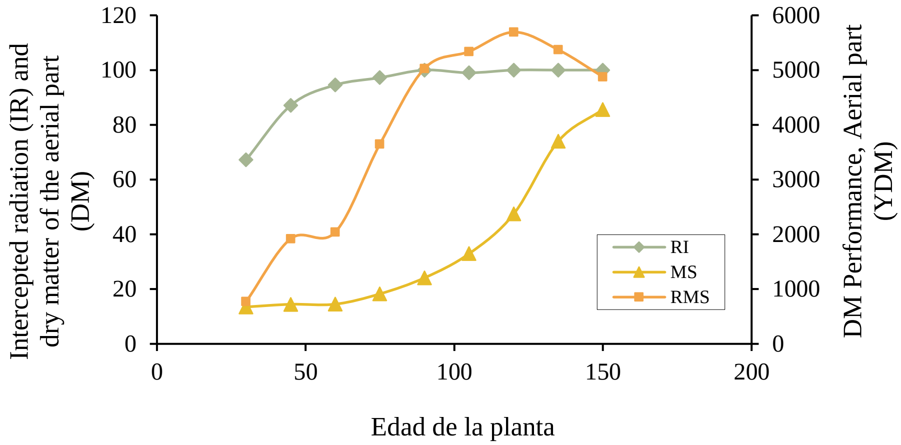


**Figure 2. The left vertical axis shows intercepted radiation (IR) in mol of intercepted photons (100 mol of incident photons)$^{-1}$, dry matter of the aerial part (DM) in g (100 g)$^{-1}$ and in the right vertical axis is read yield of DM of the aerial part (YDM), in kg ha$^{-1}$ of *Avena sativa*, variety Chihuahua.** The horizontal axis, from 30 days to 150 days old, is the same for the three variables.

Statistical differences ($p< 0.05$) in the YDM between 30, 45, 60 and 75 days were presented, with 772, 1 921, 2 042 and 3 649 kg ha$^{-1}$ respectively; however, from day 90 the differences were not significant ($p< 0.05$). The maximum YDM (5 355 kg ha$^{-1}$) was obtained at the age of 120 days (Figure 2), in the milky-massive state. Wilson *et al*. (2018) showed that the highest yield for Turquoise variety oats was obtained 112 days after sowing with 6 702 kg ha$^{-1}$ in a milky-massive state. Zartash *et al*. 2018, they reported approximately 5 000 kg ha$^{-1}$ at 160 days after planting. 6 074 kg ha$^{-1}$ of grain yield of Chihuahua oats were reported 164 days after emergence in the summer-autumn cycle (Hernández-Campuzano *et al*., 2018).

Contrary Sánchez *et al*. (2014) reported 2 887 kg ha$^{-1}$ for Chihuahua oats harvested at 86 days of age. In other studies, it was also observed that the highest yield is reached between the flowering and milky grain stages, and then decreases in the milky-massive stage (FAO, 2004). In this study, 5 371 kg ha$^{-1}$ were recorded at 135 days and 4 877 kg ha$^{-1}$ at 150 days (Figure 2). This decrease in yield can be explained because at an older age, the number of leaves decreases, due to the translocation of nutrients. The foregoing confirms that the greatest amount of biomass is obtained in stages prior to physiological maturity. In winter cereals, just before anthesis, the highest leaf area index is reached (Zartash *et al*., 2018). The increase in YDM with advancing plant age (Figure 2) agrees with Dumont *et al*. (2005) and Zartash *et al*. (2018).

Da Silva and Hernández-Garay (2010) reported that, in tropical and temperate grasses, the optimum harvest point is reached with an IR of 95 moles of intercepted photons (100 moles of incident photons) $^{-1}$. In this work, the IR at 82.5 days of age was 98.6 moles of intercepted photons (100 moles of incident photons)$^{-1}$, with a yield of leaves (L) of 1 607 kg ha$^{-1}$ (Table 1). The maximum YDM was obtained when all incident radiation was intercepted, at the age of 120 days. However, at this age the plant presented a very low L value, 776 kg ha$^{-1}$, less than half the leaf yield at 82.5 days (Table 1). Therefore, if quality is sought it is more advisable to cut the oats forage at 82.5 days, with a high IR (Figure 2), a leaf-stem ratio of 1.07, an L of 1 607 kg ha$^{-1}$ and an YDM of 4 340 kg ha$^{-1}$ (Table 1).

**Table 1. Values of the dependent variables at 82.5 days and 120 days of age, to improve quality and maximize yield, respectively.** The data refers to the cultivation of oats, Chihuahua variety.

| Dependent variable | To improve quality (82.5 days old) | To maximize yield (120 days old) |
|---|---|---|
| YDM | 4 340 | 5 355 |
| IR | 98.6 | 99.5 |
| DM | 21.2 | 53.5 |
| S | 1 658.3 | 2 224.6 |
| L | 1 607.4 | 776.2 |
| P | 572.1 | 1 789.9 |
| MM | 199.8 | 304.3 |
| W | 302.9 | 259.3 |
| L/S | 1.07 | 0.35 |

YDM= dry matter yield in kg $ha^{-1}$; IR= radiation intercepted in mole of photons intercepted (100 mole of incident photons)$^{-1}$; DM= dry matter of the aerial part in g (100 g)$^{-1}$; S= stem yield in kg $ha^{-1}$; L= leaf yield in kg $ha^{-1}$; P= panicle yield in kg $ha^{-1}$; MM = yield of dead material in kg $ha^{-1}$; W= weed yield in kg $ha^{-1}$; L/S= leaf/stem ratio.

The highest DM value was 86 g (100 g)$^{-1}$ and it was obtained at the end of the cultivation cycle (150 days), showing significant differences ($p< 0.05$) from day 60 of age onwards (Figure 2). To hay the oats, it is advisable to cut it with a humidity of no more than 25 g (100 g) $^{-1}$. Once packed, subsequent drying is very difficult and increases the possibility of fungal development. These can produce toxins and severe losses of production and profitability (Gagkaeva *et al*., 2017).

At 135 days, 26 g (100 g)$^{-1}$ of humidity, 74 g (100 g) $^{-1}$ of DM were recorded (Figure 2). However, it is not recommended to wait until that age to make the forage cut as a very low amount of leaves would be harvested, only 622 kg $ha^{-1}$. Also, the fiber content of oats could be high. This would cause decreases in consumption, digestibility and passage rate, and therefore would decrease the productive yield of the animals (Ramírez-Ordoñes *et al*., 2013). Therefore, it is suggested that the animal consume fresh oat forage at 82.5 days of age, with 21.2 g (100 g) $^{-1}$ DM.

## Botanical and morphological composition (yield components), weeds and leaf/stem ratio

Figure 3 shows the leaf, stem and panicle yields (L, S and P, respectively) of the Chihuahua variety oats at different ages. Variables T and P increased according to a logistic pattern, and variable L increased initially, after 75 days of age, decreasing until reaching very low values at the end of the cultivation cycle. Other researchers reported that S and P increase logistically as the days after planting advance (Wilson *et al*., 2018). Between harvests, the increasing values of S were different ($p< 0.05$) and the decreasing values of L were also different ($p< 0.05$).

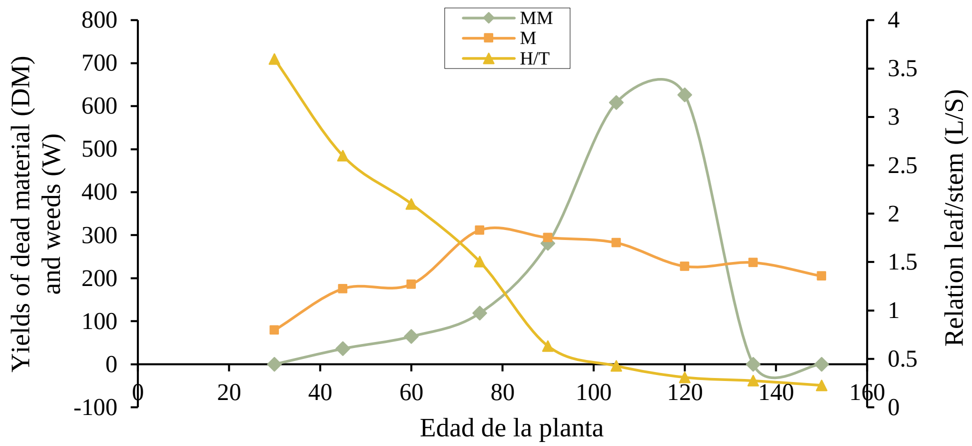


**Figure 3. On the vertical axis, yields of stem (S), leaf (L) and panicle (P) are read in kg ha$^{-1}$, of *Avena sativa*, Chihuahua variety.** The horizontal axis, from 30 days to 150 days old, is the same for the three variables.

A decrease in the yield and amount of protein was reported in the last phenological stages of the oat crop (Espitia *et al*., 2012; Mamani and Cotacallapa, 2018), which may be related to a decrease in leaves. The leaves of the lower strata do not reach the point of light compensation, their photosynthetic activity decreases and consequently they die (Wilson *et al*., 2018). The presence of panicle in the culture began to be significant ($p$< 0.05) from day 75 when it increased from 7.4 kg ha$^{-1}$ to 1 137 kg ha$^{-1}$ on day 90. From this date it remained at constant growth until reaching its highest value of 2 048 kg ha$^{-1}$ at 150 days of plant age (Figure 3). In studies carried out in Russia with crosses of the Chihuahua and Anatolischer varieties, an average of 41 days from the outbreak to the start of the panicle and 121 days from the outbreak to maturity were found (Koshkin *et al*., 2016).

The weed yield, W, (Figure 4) increased ($p$< 0.05) from day 30 (79.3 kg ha$^{-1}$) to day 75 (311.5 kg ha$^{-1}$) of plant age. After day 75 a manual weeding was applied, so on day 90 a lower value was observed (294.3 kg ha$^{-1}$) that remained constant until day 150 (204.8 kg ha$^{-1}$). In general, weeds are controlled manually during the oat cultivation cycle (Hernández-Campuzano *et al*., 2018) and no data on weed yields were found in the literature consulted.

The dead material, MM, (Figure 4) increased significantly ($p$< 0.05) with advancing plant age. At 120 days, the greatest amount of this component was recorded, with 626.2 kg ha$^{-1}$. It should be noted that from day 135 after sowing, the dead material was no longer counted as a morphological component, because due to the maturity of the plant at that age, it could no longer be differentiated from the rest of the yield components and it is reported as 0 kg ha$^{-1}$. The data of dead material coincide with those reported for the Turquoise variety from 43 days to 119 days of age (Wilson *et al*., 2018).

The leaf stem ratio (L/S) is shown in Figure 4. There were significant differences between days 30, 45, 60, 75 and 90 of age ($p$< 0.05). At the age of 75 days, an L/S of 1.5 was recorded (Figure 4), and an YDM of 3 649 kg ha$^{-1}$ (Figure 2), results that are consistent with those of Wilson *et* *al*. (2018), who reported that, for Turquoise variety oats, the highest L, combined with the highest L/S were found 77 days after planting. In this study at the age of 82.5 days the L/S ratio was 1.07, and at 120 days, for maximum yield it was 0.35. This last value coincides with the approximate value of 0.45 reported for the Chihuahua variety harvested 86 days after planting (Sánchez *et al*., 2014).

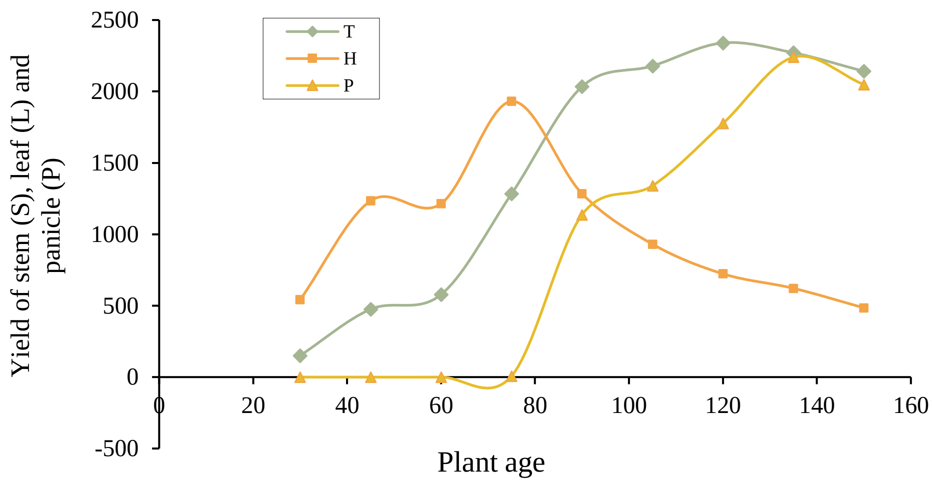


**Figure 4. Yields of dead material (DM) and weeds (W) are read on the left vertical axis. both in kg ha$^{-1}$ and in the right vertical axis is read the leaf/stem ratio (L/S) of *Avena sativa*, Chihuahua variety.** The horizontal axis, from 30 days to 150 days old, is the same for the three variables.

Ramírez-Ordoñes *et al*. (2013) indicate that there is a quadratic decrease in the amount of raw protein in the forage, when moving towards higher maturity stages of the plant. The forage oats harvested in the milky-mass state showed a yield of 6 420 kg ha$^{-1}$ with great nutritional quality (Albert *et al*., 2016; Mamani and Cotacallapa, 2018). At 82.5 days of age, when the L and S lines are crossed (Figure 3), panicle formation begins. At this point, L does not decrease too much (and neither does protein) and T does not increase too much (and neither does fiber). At this age the YDM is already quite high (4 340 kg ha$^{-1}$), compared to the YDM at 120 days (5 355 kg ha$^{-1}$). Additionally, L/S at 82.5 days is triple (1.07) of L/S at 120 days of age (0.35).

## Conclusions

The total dry matter, stems, panicle and dead material yields of the Chihuahua variety oats, grow logistically, as the age of the plant increases, while the yield of leaves and the ratio/leaf stem decrease with age.

The best phenological stage to maximize the amount of forage harvested is the milky-massive state of the grain; that is, at 120 days of age of the plant. However, if the purpose is to obtain the largest number of leaves, to ensure the nutritional quality and digestibility of the forage, the optimal cutting time is 82.5 days, with a total dry matter yield of 4 340 kg ha$^{-1}$, yield of leaf of 1 607 kg ha$^{-1}$, panicle yield of 572 kg ha$^{-1}$ and leaf-stem ratio of 1.07, with a radiation intercepted by the crop, very close to the total of the incident radiation.

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