Investigation note

Forage accumulation, morphological composition and light interception in Triticale 118 (X *Triticosecale* Wittmack)

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Abstract

The objectives were to obtain the forage accumulation curve, morphological components and light interception to determine the optimal cutting time for green forage of Triticale 118. The study was carried out in Texcoco, State of Mexico, under an irrigation system, during the winter of the year 2012-2013 (cycle 1) and 2013-2014 (cycle 2). The harvest was carried out every seven days, starting at 43 days after sowing (dds) and until the forage accumulation decreased. The average height of 20 plants, intercepted radiation (IR), dry matter accumulation, morphological composition and leaf area index (LAI) were recorded in each harvest. In cycle 1 the maximum forage accumulation was obtained at 84 dds with a yield of 1 852 kg of DM ha^{-1}, in the gleaning stage, an IR of 75% and a plant height of 52 cm were obtained, but due to a frost, it was not possible to continue sampling. In the case of cycle 2, the maximum forage accumulation occurred at 119 dds with a value of 8 733 kg of DM ha^{-1}, where the optimal cutting moment was between 77 and 91 dds, when the plant reached an IR of between 85 and 86%, LAI between 2.3 and 3.2, respectively, and an average of 58 cm. In this experiment, it was established that, with the IR, LAI and height, the optimum harvest time for Triticale 118 can be defined, obtaining quality forage.

Keywords: *Triticosecale* Wittmack, cereals, growth, phenological stage.

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Triticale (X *Triticosecale* Wittmack) is a cereal used for human consumption as grain and mainly for animal consumption in green or haymaking. The quality of the grain and the favorable dry matter yields in environments with low precipitation and poor soils, compared to other grains, such as wheat, have allowed their production to increase worldwide and the search for better cultivars (Mergoum, 2004; Ferreira *et al*., 2015). The countries that produce the grain crop the most are: Poland (1 352 013 ha), China (490 000 ha), Belarus (489 685 ha), Germany (389 000 ha), France (315 141 ha) and Spain (195 884 ha) and for the American continent they are: Canada (24 494 ha), Chile (20 122 ha) and Brazil (16 274) (FAOSTAT, 2019).

In the case of Mexico, in 2000 only 435 h1a were sown for forage and 740 ha for grain (SIAP, 2017), while for the year 2017 22 309 ha were established, of which 16 081 were for forage purposes and 6 228 for grain, highlighting in order of surface the entities of the State of Mexico (3 562 ha), Jalisco (2 263 ha), Durango (1 935 ha), Guanajuato (1 908 ha), Querétaro (1 396 ha) , Coahuila (700 ha) and Hidalgo (471 ha).

The surface of this crop has increased considerably, especially in places where water scarcity does not allow other crops such as corn to be established, making triticale a very profitable option, both for forage and grain (Lozano-del Río *et al*., 2009). Forage accumulation curves, morphological composition and intercepted radiation are tools that together can help to decide the optimal cutting moments for forages (Seville, 2001); likewise, it is important to point out that the good quality of a forage is associated with genotypes that present a greater leaf: stem relationship.

When conducting studies on perennials, some authors agreed that the higher nutritional value of plants is associated with a greater presence of leaves (Baron and Kibite, 1987; Juskiw *et al*., 2000). This phenomenon occurs when plants intercept 95% of radiation, because net growth is maximized.

It is also related to plant height, there is a practical criterion to identify optimal cutting moments in plants for perennial forage (Hodgson, 1990; Da Silva and Nascimento Jr., 2007; Da Silva and Hernández-Garay, 2010). The information available on this crop is mainly based on grain yield for human consumption, but research on forage yield and other variables is scarce and specific to the genotypes and regions in which it was carried out, so it is necessary to generate studies on accumulation of dry matter, morphological components and other characteristics to make decisions in the field on adequate cut-off dates made with the forage potential materials, in the regions favorable for this crop.

Therefore, the objective of the present study was to perform the forage accumulation, morphological composition and light interception curves to determine the optimal time for harvesting green forage in Triticale (X *Triticosecale* Wittmack) during two growth cycles.

Two experiments were carried out in field conditions, in the winter cycle 2012-2013 and winter 2013-2014, at the College of Postgraduates, Texcoco, Estado de Mexico (19° 29’ north latitude, 98° 54’ west longitude and 2 250 masl). The soil of the cultivated area is sandy crumble, with a pH of 7.8, with 2.4% organic matter (Ortiz, 1997). The climate of the place is temperate sub-humid with rains in summer, precipitation of 645 mm and average annual temperature of 15 °C, respectively (García, 1998). Meteorological data was obtained from the Autonomous University Chapingo Station located 4.1 km away (Table 1).

Table 1. Monthly average of maximum and minimum temperatures, precipitation and number of frosts. Autonomous University Chapingo Weather Station.

Month	Temperatures (°C)				Precipitation (mm)		Frosts (number)	
	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014
	Maximum	Minimum	Maximum	Minimum				
December	23.5	3.1	23.6	4.4	0	0.9	25	17
January	22.6	4.4	21.4	2.2	0	2.6	18	25
February	26	4.4	25.6	4	2.8	2.4	15	12
March	24.9	5	26.5	7.2	1.6	27.7	18	5
April	27.9	9.1	27.3	8.4	23	20.1	3	3
Total	-	-	-	-	27.4	53.7	79	62

Triticale genotype evaluated

The genotype evaluated was Triticale 118 from the College of Postgraduates. The sowing of cycle 1 was carried out on December 05, 2012 and that of cycle 02 on December 04, 2013, the sowing density used was 100 kg ha^{-1}. The experimental plots were 2 m wide by 10 m long, and three replications were established. Fertilization was 40-40-00 NPK at planting and 40 nitrogen units at the beginning of the tillering process. The experimental plots were watered nine times, at fifteen-day intervals at field capacity.

Average height of the evaluated varieties

The height of 20 plants chosen at random in each experimental unit was measured with a ruler of 1.5 m in length, registering the height data that indicated the movable mica of the ruler at the first contact with the plant.

Intercepted radiation (IR)

Before cutting the plants in the sampling units, 5 readings were taken at random, of the amount of solar radiation intercepted by the plants within each sampling unit with the Model LP-80 Ceptometer (Decagon Devices, Inc.), at 12:00 a day.

Forage accumulation

From 43 days after sowing, forage samples were harvested every 7 days, until Triticale 118 reached physiological maturity. The sampling unit was a 0.45 m^2 table, within which all the Triticale 118 plants were cut at a height of 12 cm above ground level. The harvested forage was dried to constant weight, in a forced air oven at 55 °C. With the dry weight, the forage yield per hectare was calculated. The main stages of development were identified, using the scale of Zadoks *et al*. (1974).

Morphological composition of harvested forage

To estimate the morphological components, a subsample of 100 g of harvested forage was taken. The subsample was separated into leaves, stems, ears and dead material. Each component was placed in identified industrial paper bags and dried in a forced air stove at 55 °C to constant weight and weighed with a digital scale (Gramera Brand Model hh). The dry weight in kg ha^{-1} of each component was estimated.

Leaf area index (LAI)

Before drying the leaves obtained from the subsample (100 g), their leaf area was determined with an integrator model LI-3100 (LI-COR, inc.). The LAI was estimated with the data obtained from the leaf area and the area of the sampling unit.

Statistical analysis

The experimental design used was in repeated measures over time with three repetitions. The data of the measurements made were analyzed with the SAS GLM (Statistical Analysis System Version 9.0 for Windows) procedure. Tukey's test was used to compare means (α= 0.05).

Dry matter yield

In cycle 1, the maximum recorded forage accumulation was found at 84 dds, with a yield of 1 852 kg ha^{-1} when it was in ear (52, Zadoks). This was the last sampling date due to the premature death of the plants caused by a frost, which was the most intense throughout the cycle (Figure 1).

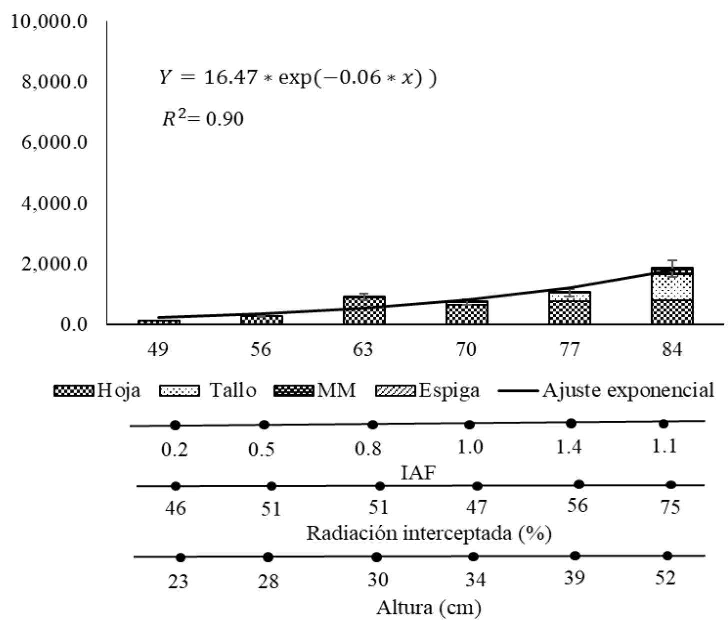

Figure 1. DM accumulation, morphological composition, LAI, IR and height of Triticale 118 in winter.

In the case of cycle 2 the highest dry matter accumulation value was 8 733 kg of DM ha^{-1}, this was found at 119 dds, since at 126 dds the dry matter value decreased to 7 653 kg of DM ha^{-1} (Figure 2). Comparing the production cycles, from sowing to 84 days, the best performance was observed in cycle 2, since as indicated in cycle 1, the maximum accumulation of dry matter was 1 852 kg of DM ha^{-1}, while for the same date in cycle 2 it was 2 85 kg of DM^{-1}, a situation that was due to the greater presence of frost in cycle 1 with a total of 79, while in cycle two there were only 72 (Table 1). It is worth mentioning that this type of crops are resistant to low temperatures and require accumulation of cold hours to complete their development cycle, low temperatures also affect their development and very intense frosts can cause plant death (Llera and Cruz, 2014).

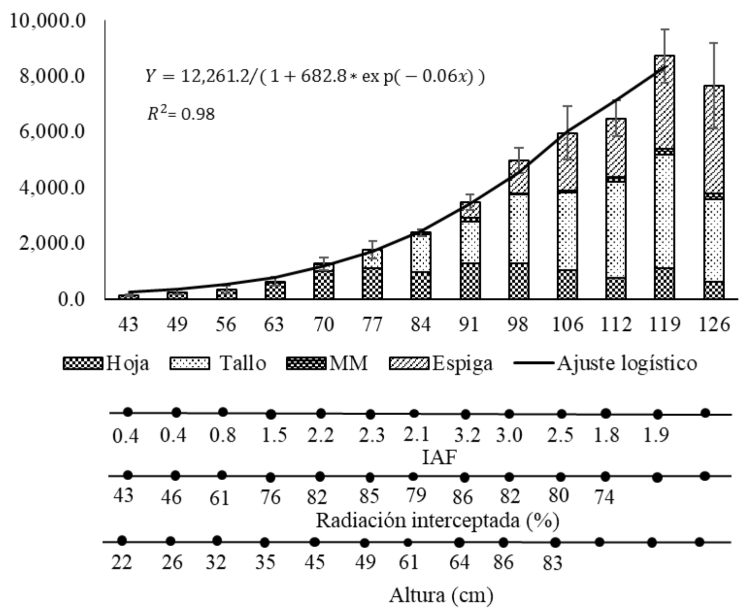

Figure 2. DM accumulation, morphological composition, LAI, IR and height of Triticale 118 in winter.

In the second cycle, it is in which the highest DM yield is reached at 119 dds, which is why it is considered a late genotype, for this reason Morant *et al*. (2007), mention that the most important characteristics that forage wheat and triticales should possess are having a longer biological cycle and being adapted to early sowing, which would allow having a longer vegetative phase for a greater number of cuts.

Morphological composition

In cycle 1, the best leaf yields in combination with the highest leaf/stem ratio were found between 63 and 77 dds with average leaf and stem yields of 784 and 273 kg ha^{-1}, since, for the following sampling, the percentage of leaf in relation to the stem was equalized, which detracts from the quality of the forage. In cycle 2, the greatest contribution of leaves to total yield and the best leaf/stem ratio was also found between 77 and 91 dds in the enchanting state (35, Zadoks) with leaf and stem of 1 111 and 661 kg ha^{-1}, in the case of 77 dds.

Similar data is reported by Keles *et al*. (2013), that when evaluating the yield of triticale in the tillering and mowing stages, reported that winter cereals can be grazed until the mowing stage, without causing large reductions in the yield of regrowth and total forage.

Regarding the ear, the data indicates that from 91 dds it appears, with a yield of 550 kg of DM ha^{-1}, and later up to 126 dds with a yield of 3 843 kg of DM ha^{-1}, situation that the quality of forage decreases when the proportion of this morphological component is higher; similar results have been reported in the literature (Pérez-Amaro *et al*., 2004).

The quality of a forage is generally related to the age of the plants, since, in advanced stages of development, senescent leaves tend to fall, which was reflected in the latest samplings; likewise, a shadow effect is produced on the lower leaves by those of the upper stratum, causing their death, in cycle 2 for the 122 dds a quantity of 147 kg ha^{-1} of dead matter was observed, mainly senescent leaves (Chapman and Lemaire, 1993).

In the case of the ears, these also form in advanced stages of development, initiating a process of translocation of photosynthates from the stems and the leaves for the filling of grain, with the consequent death of the leaves that are those that provide the highest quality to the harvested forage (Juskiw *et al*., 2000).

Foliar area index

In the cycle 1 experiment, the LAI variable reached its highest value on the 77 dds, which was 1.4, which coincides with the largest amount of leaf in relation to the stem; however, due to the black frost that affected this cycle, it was not possible to see if the LAI value could have increased. The opposite case occurred in cycle 2, in which it was observed that the highest amount of LAI was at 91 dds with 3.2, which coincides with a crop that still had a significant percentage of leaf in relation to the stem, since according the proportion of stem and spike in the crop increased, the LAI gradually decreased to 1.9 at 119 dds.

The LAI is a very important variable if it is considered to have the maximum dry matter yield, since Parsons and Penning (1988) mention that when 95% of incident light is intercepted by the canopy and the average forage accumulation rate reaches its maximum, there is a balance between the processes of maximum growth and senescence that allows a greater accumulation and quality of forage, due to the greater amount of leaf present. Therefore, in a practical way, the IR and the LAI have been related to height, allowing to define optimal dates for cutting forage, with good nutritional quality, in addition to allowing the regrowth of plants.

Intercepted radiation

There is no information on the optimum harvest point in relation to the radiation intercepted in small grain cereals for forage production, but in works carried out in tropical and temperate pastures, Da Silva and Hernández (2010) observed that the optimal harvest point is when the plants reach 95% light interception and it is related to the greater contribution of leaves to the yield, in this case no cycle reached 95% IR, for the case of cycle 1 the maximum value was 75%, at 84 dds.

In the case of cycle 2, the maximum IR was 86%, a value that was obtained at 91 dds, later this variable possibly decreased due to the lower production of leaves in relation to the stems and the spikes, also, the low temperatures they were also a negative factor for the development of the leaves and that the crop could reach 95 of light interception (Juskiw *et al*., 2000). Likewise, it would be important in future studies to evaluate different planting densities to determine if this variable is related to IR.

Height

In the case of height, the maximum reached during cycle 1 was 52 cm at 84 days. For cycle 2 it was 98 days with a height of 86 cm, since in the following samplings there was senescence and death of foliage, which apparently affects the height when there is leaf fall from the upper part. In this case, height is the most practical tool if you want to easily recommend an ideal cut point to producers, however, this variable depends on environmental conditions, since for example in cycle 1 at 77 days the crop reached an average height of 39 cm; while for the same date in cycle 2 the height registered was 49 cm, which is due to the greater presence of frost in the first growing cycle, which affects its development, so it is important to assess radiation intercepted.

A variable that influences the height of a forage is the planting time, since some authors such as Mendoza *et al*. (2011), evaluated three winter planting dates (November 09 and 23 and December 07), finding heights of 104 and 102 cm on the first two dates respectively, and a height of just 68 cm on that of December 07 . For this experiment, the planting date was December 5; however, plant heights of 86 cm were reached.

With the DM accumulation data it can be seen that triticale is a good option as feed for cutting or grazing, similar results were found by Zamora *et al*. (2002), who compared triticales with oats, barley and ryegrass, obtaining the same yields as oats; as well as winter triticales were compared in two cuts, in which they maintained quality and performance even in the second cut.

Conclusions

Triticale 118 is a material that can be used as green forage during winter, as it is a long-cycle genotype and has good forage aptitude in terms of dry matter yield and leaf quantity. The optimum cutting moment for forage in cycle 2 was found in encañe (35 Zadoks-77 to 91 dds), since in this state of development is when the highest leaf and LAI yields were found and there was coincidence with the most high light intercepts. Intercepted radiation, LAI and height can be criteria used to determine the optimum cutting moment for forage in triticale plants.

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