Article

Yield of five varieties of lucerne during four years of evaluation

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Abstract

The aim of this study was characterize the forage production of five lucerne varieties in Montecillos, Texcoco, state of Mexico. Grassland with varieties Cuf-101, Moapa, Oaxaca and Valenciana were established in 2004, in which the annual dry matter yield (ADMY), seasonal yield (SY), forage accumulation rate (FAR) and leaf: stem ratio. The data were analyzed by the GLM procedure of SAS and comparison of means by the Tukey test. Changes by season, variety and years and their interactions were analyzed. Differences (p< 0.05) in ADMY, MSE, FAR and leaf: stem relationship were found between varieties, seasons and years. During the first year, higher ADMY was observed, and decreased to 57% at the end of the evaluation period. The Oaxaca variety maintained the highest production at the end of the evaluation and Moapa the lowest. In the SY it was observed that in summer it had the highest performance and in winter it decreased about 50%, a trend that was maintained during the evaluation period, this difference decreases over the years, with a more constant accumulation of DM in year. The leaf: stem ratio is higher in the second year where the Cuf-101 and Valenciana varieties registered the highest relationship in the winter season. In conclusion, the genotype of the lucerne variety influences the dry matter yield by season, year and production period, where the season of greatest DM production is summer.

Keywords: biomass production, forage accumulation, lucerne, seasonal yield.

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Introduction

Lucerne cultivation has played an important role in animal production for many years; however, its use in production systems has undergone changes due to climatic variations, which have made it necessary to examine the limitations in current traditional systems and the potential of lucerne as a food source for ruminants (Bouton, 2012).

In this sense, the yield, quality and persistence of lucerne grasslands is strongly influenced by the frequency of defoliation, which is a critical and determining relationship in the management of the grassland (Chen *et al*., 2012) since it must compensate the biomass yield, quality of the forage produced and the persistence of the pasture, which together would allow harvesting the greatest amount of forage, with the highest nutritional value and keeping the pasture in good condition for more years (Teixeira *et al*., 2008) .

Conditions that are linked to the climatic scenarios, regrowth capacity of the variety used in the grassland and the nutritional requirements of the animal species that will be fed with the forage (Chen *et al*., 2012). Like all forage species, the dry matter yield of lucerne varies; throughout time, defoliation management must be defined seasonally based on growth rate (Hernández-Garay *et al*., 1992; Richards, 1993), which represents the balance between growth rate and loss of tissue by senescence and decomposition.

Which changes with the environmental conditions of each season of the year (Lemaire *et al*., 2009; Valentine *et al*., 1999), therefore, the knowledge of the seasonal changes in the growth rate of the different forage species (Hodgson, 1990) allows to determine the optimum harvest frequency and intensity of lucerne and thus obtain the highest yield of high quality dry matter, without affecting its persistence (Hodgson, 1990; Valentine *et al*., 1999).

In this regard, Harvey *et al*. (2014) mentioned that, in the evaluations carried out in New Zealand, the lucerne cultivars evaluated have been classified based on their winter activity, a trait of the variety that determines the height of the plant above the ground during the autumn and winter, this is known as autumn latency (AL). The AL class is assigned based on measurements of plant height in the autumn, after allowing regrowth after uniform defoliation.

This quality of forage yield in lucerne is important due to the marked decrease in the growth rate of the species, which generates a longer period of rest to avoid the loss of plants and deterioration of the grassland (Mendoza *et al*., 2010). Therefore, the objective of the present study was to characterize the growth and dry matter yield of five lucerne varieties during four years of grassland evaluation, as well as to determine seasonal variations in forage yield.

Materials and methods

Location and characteristics of the study area

The study was carried out in Montecillo, Texcoco, State of Mexico, located at 19° 29’ north latitude and 98° 53’ west longitude at 2 250 masl. With a sub-humid temperate climate and an annual rainfall of 645 mm. The type of soil is clay with a pH of 8.08, electrical conductivity of

0.61 dS m^{-1}, with 3.28% of organic matter, total N with 0.21%, phosphorus with 20.8 mg kg^{-1}, potassium with 0.39 meq L^{-1}, Calcium 2.52 meq L^{-1} and magnesium 1.35 meq L^{-1}.

The treatments used were five commercial varieties of lucerne (San Miguel, Oaxaca, Moapa, Valenciana and Cuf-101). Which were harvested every four weeks in the spring and summer seasons, every five weeks in the autumn and every six weeks in the winter. A randomized complete block design with three replications was used in an arrangement of plots divided in space and time, the experimental unit consisted of a 3 x 3 m plot.

Soil preparation was carried out one month before sowing, with a fallow with disc plow to turn the soil over, incorporate existing material, eliminate some pests and weeds and loosen the topsoil. Later, two days before sowing, two steps of the disc harrow were applied to reduce the existing clods and to have a good sowing bed due to the type of small seed of the crop to be established.

The sowing of the lucerne varieties was carried out on March 16, 2004, at a sowing density of 30 kg ha^{-1}, for which the seed was deposited broadcast on the soil surface, previously fertilized with a dose of 60-140 -00 (NPK) and covered with a rake, the planting density was adjusted, with the weight of the seed and the percentage of germination estimated before planting, so that all the varieties had approximately the same number of seeds sown per m^2.

A second fertilization was carried out at 14 months after sowing (May 20), with a dose of 40-00-00 (N-P-K). The commercial fertilizers used to cover the required doses were urea (46% N) and triple superphosphate (46% P). 90 days after sowing (DDS), a uniform cut was made with a scythe at a height of 5 cm above the soil surface to eliminate weeds. The cuts started 120 DDS and so on every four weeks in the spring and summer seasons, every five weeks in the autumn and every six weeks in the winter.

The first irrigation with aspersion was applied the day after sowing, later the second irrigation was given 7 DDS to favor the emergence of the seedlings, the subsequent irrigations before establishing the storm were applied every seven days until June and once the temporary, in October the irrigations were applied every 15 days and so on every year of evaluation.

Variables evaluated

Annual dry matter yield (ADMY, t ha^{-1} $year^{-1}$)

The cuts were made according to the season of the year in a fixed table of 0.25 m^2. The harvested forage was cleaned of impurities, weeds and soil, weighed in green and the data was recorded; immediately afterwards, a 150 g subsample was taken, which was separated into leaves, stems and dead or senescent material.

These forage components were placed in a paper bag, separately and brought to a forced air stove, at a temperature of 55 °C for 72 h until constant weight and the percentage of dry matter was determined to be later applied to the total sample and the dry matter obtained in the quadrant was determined and with this, convert the data to tons per hectare. In this way, four values were obtained: dry matter yield of leaf, stem, dead or senescent material and the sum of the three was the total DMY. The dry matter yields and that of its morphological components were obtained monthly and by season.

Yield of dry matter by season (YDMS, t ha^{-1} station^{-1})

The dry matter yield was determined for each harvest, which was added to those corresponding to each season of the year.

Forage accumulation rate (kg ha^{-1})

It was determined by estimating the dry matter yield divided by the number of days in the interval between cuttings.

Leaf:stem ratio (L:S)

It was obtained by dividing the weight of the leaves by the weight of the stems.

Statistical analysis

The variables studied were evaluated by analysis of variance with the statistical program Statistical Analysis System, Institute Inc. 1990 (SAS) by the GLM procedure (SAS, 9.4; SAS Intitute Inc., 2012) and the mean comparisons were carried out by Tukey's tests.

Results and discussion

The annual dry matter yield showed significant differences ($p< 0.05$) between species and between years, where the Oaxaca and San Miguel varieties had the highest annual yield (Figure 1). The annual dry matter yield results show that the highest biomass values were recorded in the first year of the establishment of the meadow, for the second year, a decrease in the dry matter yield of forage was observed, which was recovered in the third year, except for the Valencian variety, which showed similar dry matter values between the second and third year.

The DMY of the grasslands decreases over the years, reaching an average yield of 43%, compared to that of the first year. This item has important differences, since the Moapa variety is the one that registered the lowest yield at the end of the evaluation (43% with respect to its first-year production) and the Oaxaca variety maintained the highest DMY after 4 years of evaluation (53% compared to the first year).

According to the total dry matter yield of the four years of evaluation, the varieties can be ordered in descending order, Oaxaca, Moapa, San Miguel, Cuf-101 and Valenciana with 108.4, 103.8, 100.4, 87.2 and 85.9 T DM ha^{-1}, respectively.

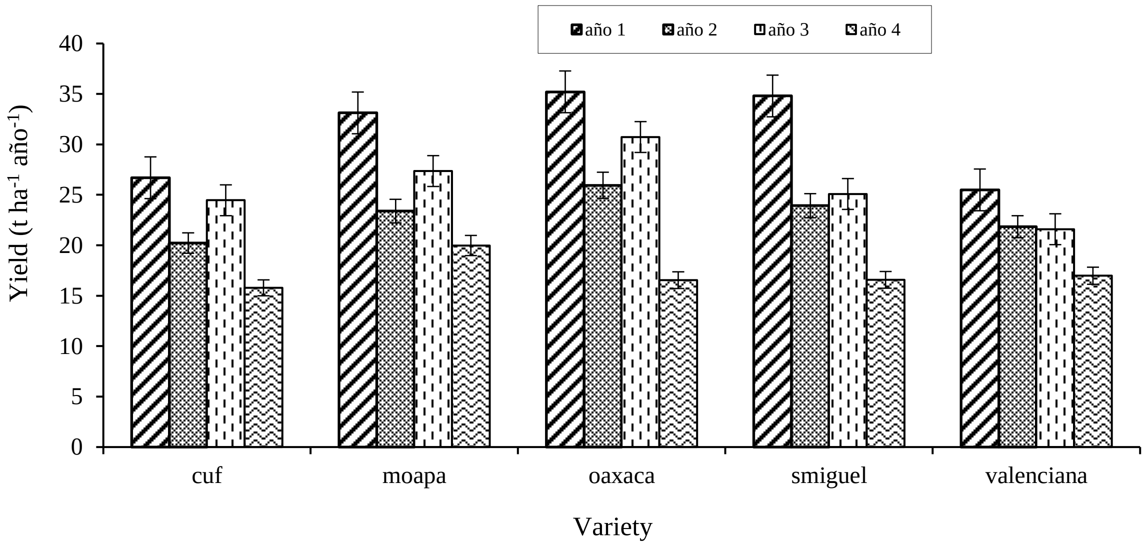

Figure 1. Annual yield of 5 varieties of lucerne over a 4 year period in Montecillo, Texcoco, State of Mexico.

The results obtained from the annual dry matter yield of forage are similar to those reported by Mendoza *et al*. (2010), those who, when evaluating the response of an lucerne meadow with the San Miguel variety with different cutting frequencies, obtained that with the highest intervals between cutting (6 weeks in spring and summer and 7 weeks in autumn winter) a yield of 34.54 T DM ha^{-1} year^{-1}, similar to those reported in the first year of harvest in this study.

However, they are superior to those reported by Rojas *et al*. (2019) who when evaluating five lucerne varieties observed annual dry matter yields of between 14 488 and 20 643 T DM ha^{-1} year^{-1}; in this regard, Alvarez *et al*. (2018) reported annual dry matter yields in 10 varieties of lucerne between 7 890 and 14 510 T DM ha^{-1} yr^{-1}. In turn, Morales *et al*. (2006) when evaluating the yield of 14 varieties of lucerne with fertigation in the Mixteca of Oaxaca showed dry matter yields of between 46.99 and 52.95 T DM ha^{-1} year^{-1}, results higher than those recorded in this study.

The dry matter yield per season showed differences (p< 0.05) between stations, in general, when making the comparison in the average DMY per season, it is shown that the highest yields were in summer, where 34.1% of that occurred in the period. evaluation (Table 1). In general, the evaluated varieties show a decrease in winter forage production, where 17.6% of the year's production is recorded; that is, about 50% of the production registered in summer and 72% of what is produced in the summer and autumn seasons, this indicates that, in order to carry out adequate planning in the forage resource of the lucerne grassland, it is necessary to consider this decrease in dry matter yield.

Table 1. Average dry matter yield per season (t ha^{-1}) of five lucerne varieties in a 4-year period in Montecillo, Texcoco, State of Mexico.

Variety	Spring	Summer	Autumn	Winter	SEM
Cuf-101	5.303 Bc	8.289 Ab	5.871 Bb	3.652 Cc	0.75
Moapa	6.013 Bb	9.668 Aa	6.626 Ba	5.157 Ca	0.92
Oaxaca	7.545 Ba	9.496 Aa	5.978 Ca	5.444 Ca	0.87
San Miguel	6.332 Bb	9.767 Aa	6.883 Ba	4.896 Cb	0.79
Valenciana	6.032 Bb	7.123 Ac	6.139 Ba	3.689 Cc	0.65
Average	6.245	8.869	6.299	4.586	
SEM	0.96	0.56	0.81	0.74	

A, B, C= means values in the same row with different literals, are different (p<0.05). a, b, c= means values in the same column with different literals are different (p< 0.05).

These results coincide with that reported by Álvarez *et al*. (2018) who, when evaluating the dry matter yield of forage of ten varieties of lucerne for four years, observed that the highest forage yields are in the summer season, followed by spring, autumn and winter in that descending order.

Similarly, Rojas *et al*. (2018), when evaluating the seasonal performance of five lucerne varieties, reported the highest forage productions in the summer season and the lowest in December, a trend equal to that observed in the present study. The results of dry matter yield by season in each year are shown in Figure 2, where it is feasible to observe that there is a similar behavior in dry matter yield in each season of the year in the four years of study.

When making an analysis by season and time of year, it is shown that in the first year there are the greatest differences in the seasonal dry matter yield, as the years pass, the dry matter yields are more constant, due to the decrease in production in the summer season. The Oaxaca variety is the one that maintained the least changes in forage yield over the years; however, at the end of the evaluation period (fourth year) the yield falls to 50% of what it generated in the summer period in previous years.

The yield of dry matter per season, under irrigation conditions, is related to variations in environmental temperature, which critically affects crops due to the changes it generates in different processes of plant development, these effects are related Apparently, with the different genotypes of a species, which have been adapted to the temperature conditions of a specific area (Serge *et al*., 2017), in this regard Dhot *et al*. (2013) mentioned that the low yields and forage harvest in the periods of less growth, have a negative effect on the survival of the plants and in the case of lucerne, it has been attributed to the low accumulation of carbohydrate reserves in the roots and since there is a period that allows a good accumulation of reserves in the roots, it generates an adequate yield in the spring and summer periods.

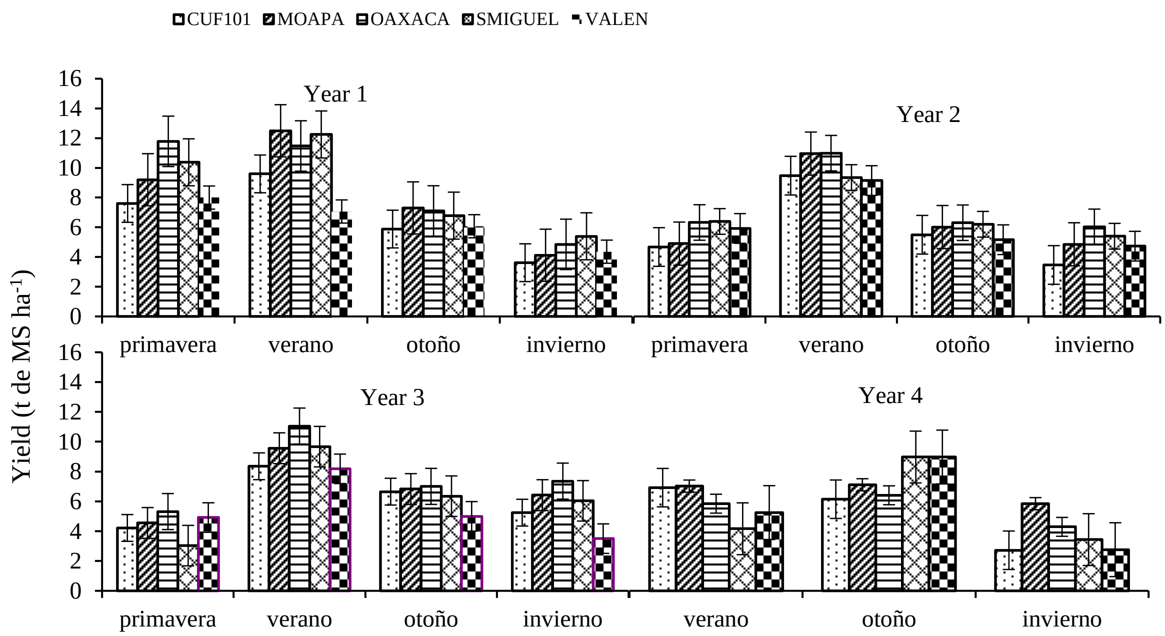

Figure 2. Dry matter yield per season per year of five lucerne varieties in Montecillo, Texcoco, State of Mexico.

In this sense, Teixeira *et al*. (2007) mentioned that when evaluating the accumulation of C and N reserves in lucerne grasslands with different harvest regimes, they observed that the accumulation of these elements in the roots follow seasonal patterns of accumulation and depletion in the crop, regardless of the regime of harvest, and emphasize the importance of a long interval between defoliation in mid-summer and autumn, as one of the best strategies for replenishing reserves, which impacts the growth potential during the following growth in early spring and with it, the persistence of the grassland.

The forage accumulation rate showed differences ($p< 0.05$) between seasons and years, where the variety that had the best average was Oaxaca with 19% more than the Cuf-101 variety that had the lowest average throughout the study and close 10% more than the other varieties (Table 2).

Table 2. Seasonal forage accumulation rate (kg ha^{-1} d^{-1}) of five varieties of lucerne over a period of four years in Montecillo, Texcoco, State of Mexico.

Variety	Summer	Autumn	Winter	Spring	SEM
Cuf	97.44 Ab	58.74 Bb	47.8 Cc	59.26 Bd	3.25
Moapa	107.76 Aa	66.07 Ba	59.35 C	68.96 Bc	4.73
Oaxaca	106.16 Aa	65.78 Da	73.76 Ca	79.25 Bb	3.14
San Miguel	86.62 Ad	66.45 Ca	62.82 Cb	77.82 Bb	2.99
Valenciana	92.64 Ac	54.82 Bb	46.82 Cc	88.23 Aa	5.9
Average	98.12	62.37	58.11	74.71	
SEM	1.89	2.07	2.17	1.9	

A, B, C= means values in the same row with different literals, are different ($p< 0.05$). a, b, c= means values in the same column with different literals are different ($p< 0.05$).

There are differences in the forage accumulation rate depending on the season of the year, thus it is shown that the descending order is summer, spring, autumn and winter with 98.12, 74.71, 62.37 and 58.11 kg ha^{-1} d^{-1}; respectively, a trend that is related to seasonal forage yield, since the accumulation per day, at the end of the harvest period, will be part of the yield of each variety. The behavior of the accumulation rate in the evaluation period based on the different seasons of the year is shown in Figure 3. Significant differences were observed between years, varieties and seasons, as well as their interactions.

It was observed that in the first year there was the highest rate of forage accumulation, mainly in the summer season; however, in the first year, in the spring season, the Valencian variety had its maximum accumulation rate, higher than all other years. For the second year, the accumulation rate was reduced in all varieties about 20% of the values registered in the first year and for the third year, the accumulation rate had an increase of 10.3% with respect to year two.

The trends in the accumulation rate are similar among the varieties; however, there are differences in the behavior between varieties in the same year, in the different seasons and between seasons in the different years. Thus, it is shown that in the first year in the spring season, the Valencian variety had a higher yield with respect to the other varieties.

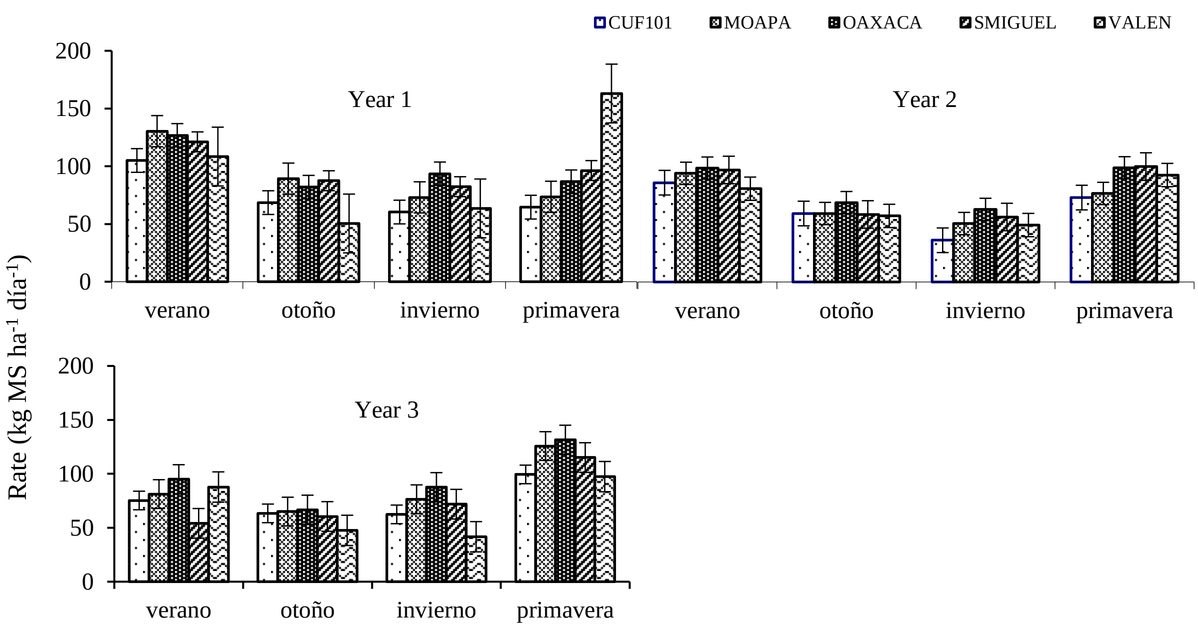

Figure 3. Forage accumulation rate of 5 varieties of lucerne during four years in Montecillos, Texcoco, State of Mexico.

The observed values of in the Forage Accumulation Rate (FAR) are higher than those reported by Rojas *et al*. (2005) who when evaluating 5 varieties of lucerne reported average values of 70, 46, 25, 50 kg DM Ha^{-1} d^{-1}, for summer, autumn, winter and spring, respectively, in the same way, they differ from what was observed in the present study regarding seasonal trend, since the results of the present study indicate a higher FAR in spring.

In this regard, Montes *et al*. (2014) when evaluating the accumulation of forage in Oaxaca of a creole genotype, reported that there are variations in this variable at different times of the year, they mentioned that in spring they obtained the maximum values in a range of 23 and 57 kg DM Ha^{-1} d_{-1} and between 24 and 52 DM ha^{-1} d^{-1} in winter, where the lowest FAR was recorded, this as a function of the period of rest, a seasonal trend similar to that observed in the present study. Similarly, Hernández-Garay *et al*. (2012) when evaluating the FAR at different grazing pressures they observed a seasonal trend similar to that observed in the present study and similar FAR with ranges ranging from 55-95, 75-79, 44-52 and 107-81 ha^{-1} d^{-1} in summer, autumn, winter and spring, respectively.

The adaptation of different varieties of lucerne to different climatic conditions has led to different models of growth and forage accumulation. During the winter period, lucerne has active growth at different growth rates, with an influence of low temperatures at respect; it is important to determine the factors that affect the growth of lucerne to establish production models.

In addition to the need to determine the varieties of lucerne that show the highest degree of winter dormancy in the different production areas in the country, due to the fact that the response of lucerne to the different climatic variables is not constant throughout the seasons of the year; therefore, to develop prediction models there cannot be a single model for the whole year, but it must be according to the time or season of the year.

Different studies have shown the changes in growth in the seasons of the year, which generates fluctuations in the photoperiod, which, in combination with changes in temperatures and evapotranspiration rate, affects the growth rate, therefore, it is necessary to modify the periods between cuts to ensure the formation of root reserves

The leaf:stem relationship showed differences ($p< 0.05$) between varieties, seasons and years (Figure 4). It is observed that the highest value is in the second year, where the Cuf and Valenciana varieties registered up to 2; that is, twice the leaf with respect to the stem; however, the other varieties in this year had a relationship close to one. For the third year, this ratio fell below 0.5, mainly in the summer season and the highest leaf proportions in the winter and spring seasons, a very similar trend in the fourth year, where the leaf: stem ratio did not change.

The leaf: stem relationship observed in the present study is similar to that reported by Montes *et al*. (2016), who, when evaluating the performance of the variety Oaxaca creole, observed a leaf: stem relationship that ranges from 0.7 to 1.7 in the study period with higher values in the spring and summer seasons, a trend that differs from that observed in the present study; likewise, when evaluating the yield of five lucerne varieties, they determined the leaf: stem relationship and reported that the Moapa, Valencia and Cuf varieties had the highest values of this relationship (0.72, 0.79 and 0.8, respectively).

However, they obtained lower values than those observed in the second year of this study, but very similar to those of the third and fourth years. In this regard, Morales *et al*. (2006) when evaluating 14 varieties of lucerne reported values similar to those reported in years three and four of this study, ranging from 0.619 in the Bajio 76 variety to 0.8 in the Moapa variety, which is similar to what was observed in the present study.

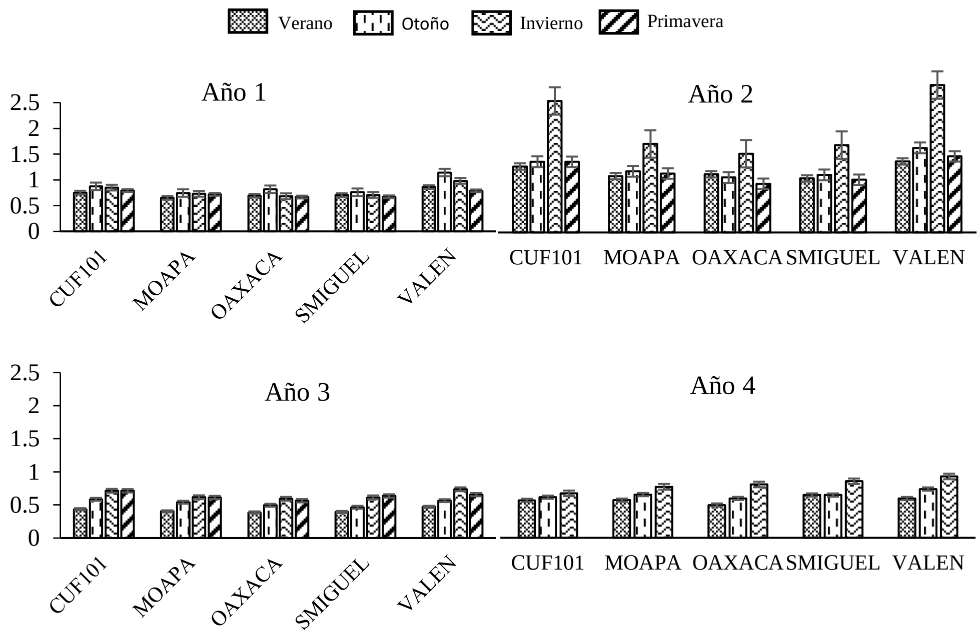

Figure 4. Leaf: stem relationship of 5 varieties of lucerne for four years in Montecillos, Texcoco, State of Mexico

In forage production, the interest is focused on the accumulation of dry matter in the leaves, since it is the part of the plant that provides the highest content of nutrients (Atencio *et al*., 2014); in such a way that the growth of the crops is affected in the winter period, the leaf area is a determining factor of the final yield and is affected by the losses that occur during vegetative growth.

The apparent change in the proportion of leaves at the end could be the result of the modification in the development of the stem, which allows greater generation of leaves, or an inaccurate determination of the base temperature (Gabrielle *et al*., 1998). In this regard, Gastal *et al*. (1992) determined that the appearance and development of leaves in plants, in most of the growth of crops, the rate of leaf area expansion is driven by the assimilation of carbon and the division between plant organs.

Assimilated partition models remain empirical and difficult to validate. The suggested approach is related to temperature and N, while carbon assimilation is not considered. The relative independence between the rate of foliar expansion and the assimilation of carbon at the canopy level is explained by the various compensations that take place between growth, in terms of accumulation, assimilation and growth depending on the size of the plant.

In this regard, Simon and Lemaire (1987) mentioned that the leaf area index is decisive for the development of stems, in case the leaf area is very low, the temperature and availability of nitrogen for the plant becomes a critical factor for the development of the stems and possibly for the persistence of the plant, likewise, more information related to canopy architecture is required and light conditions that better explain the importance of foliar development in plant growth.

Conclusions

The production and yield of dry matter in the lucerne crop is higher during the first year; in the fourth year of production they decline by up to 50%, likewise, the leaf: stem ratio was affected by the variety, season of the year and year of production. The genotype and the season of the year influence the dry matter yield, being summer the season that shows the best conditions for a higher forage accumulation rate and dry matter yield, while winter shows the opposite.

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