UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
FACULTAD DE CIENCIAS FORESTALES
SUBDIRECCIÓN DE POSGRADO

PERFIL NUTRICIONAL DE ARBUSTIVAS DEL MATORRAL ESPINOSO TAMAULIPECO CONSUMIDAS POR EL VENADO COLA BLANCA

TESIS

Como requisito parcial para obtener el grado de

DOCTOR EN CIENCIAS CON ESPECIALIDAD EN MANEJO DE RECURSOS NATURALES

Presenta

MARÍA DEL SOCORRO ALVARADO

LINARES, NUEVO LEÓN, MÉXICO **FEBRERO DE 2013**

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DEDICATORIA

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CONTENIDO

ÍNDICE DE TABLAS

RESUMEN

El Matorral Espinoso Tamaulipeco tiene una diversidad de especies de plantas leñosas adaptadas a las condiciones extremas de temperatura y precipitación de esta zona semiárida. El objetivo general fue determinar la composición química y digestibilidad de 11 arbustivas nativas: *Acacia amentacea*, *Castela erecta texana, Celtis pallida, Croton cortesianus, Forestiera angustifolia*, *Karwinskia humboldtiana*, *Lantana macropoda, Leucophyllum frutescens*, *Prosopis laevigata*, *Syderoxylon celastrinum* y *Zanthoxylum fagara;* el contenido de macro y micro nutrientes de cinco especies: *C. erecta, C. pallida, F. angustifolia, L. macropoda* y *Z. fagara.* Se realizó un muestreo estacional durante dos años en tres sitios: China, Linares y Los Ramones, Nuevo León. Los macro y micro nutrimentos para *C. erecta, C. pallida, F. angustifolia*, *L. macropoda* y *Z. fagara* tuvieron diferencias significativas ($P<0.001$) en la triple interacción (sitio*año*estación), cuyo contenido por sitio fue: Linares>Los Ramones>China superior al requerimiento mínimo (expresados en g kg^{-1} de Materia Seca) para el mantenimiento del venado cola blanca: Ca (4.5), K (6.0), Mg (1.0), Na (1.0) excepto en el caso del fósforo. Los micro nutrimentos (expresados en mg kg^{-1} de materia seca) tuvieron diferencias significativas ($P<0.001$) en la triple interacción (sitio*año*estación) donde el contenido de Fe (40) y Mn (30) satisface los requerimientos nutricionales del venado cola blanca pero el Zn y el Cu sólo de forma marginal con las especies *F. angustifolia* - *L. macropoda* y *L. macropoda* - *Z. fagara*, respectivamente. Se encontraron diferencias significativas ($P<0.001$) en la triple interacción (sitio*año*estación) de la composición química en las once especies estudiadas, pero sólo *C. pallida*, *Z. fagara* y *F. angustifolia* tuvieron los atributos nutricionales más favorables:

mayor contenido de proteína cruda (16%), bajo contenido de pared celular (40% en *C. pallida* y *F. angustifolia*) y lignina (8% en *C. pallida* y *Z. fagara*), mayor digestibilidad de la materia seca (superior al 60%), mayor contenido de energía digestible y energía metabolizable, especialmente durante el invierno y bajo contenido de INDF. Pese a que no es reportada como una especie preferida, *C. pallida* podría ser valiosa para el venado como especie de emergencia, debido a los valores de las variables indicadoras de calidad nutrimental que resultaron en el presente estudio. En general todas las especies son forrajes bajos en energía para satisfacer los requerimientos del venado cola blanca en mantenimiento y producción. Por lo anterior, se destaca la importancia de la diversidad en el hábitat y por lo tanto en la dieta del venado cola blanca texano. No obstante se hacen necesarios estudios exhaustivos sobre las particularidades nutricionales de estas especies y sobre todo en las capacidades propias del venado cola blanca para aprovecharlas.

SUMMARY

The Tamaulipan thornscrub ecosystem has a diversity of woody plants species which are used as forage by white-tailed deer, these species are adapted to the extreme conditions of low rainfall and high temperature, typical of this semiarid area. The general objective of the study was to determine chemical composition, macro and micro nutrients contents and digestibility of *Acacia amentacea, Castela erecta texana*, *Celtis pallida, Croton cortesianus, Forestiera angustifolia*, *Karwinskia humboldtiana*, *Lantana macropoda, Leucophyllum frutescens, Prosopis laevigata, Syderoxylon celastrinum* and *Zanthoxylum fagara.* The samples were collected on a seasonally basis during two years in the counties of China, Linares and Los Ramones, in Nuevo Leon state, Mexico. The macro and micro nutrients to *C. erecta*, *C. pallida, F. angustifolia*, *L. macropoda* and *Z. fagara* had significative differences (P<0.001) in the triple interaction (site*year*season), their content by site was: Linares>Los Ramones>China higher to the minimum maintenance requirement of the white-tailed deer (expressed in g kg^{-1} of dry matter) Ca (4.5), K (6.0), Mg (1.0), Na (1.0) except in phosphorous. The micro nutrients (expressed in mg kg^{-1} of dry matter) had significative differences (P<0.001) in the triple interaction (site*year*season) where the content of Fe (40) and Mn (30) meet the minimum nutritional requirements of maintenance of wild and domestic small ruminants but to Zn and Cu only marginally with *F. angustifolia* - *L. macropoda* and *L. macropoda* - *Z. fagara*, respectively. There were differences (P<0.001) in the triple interaction (site*year*season) of the eleven shrub species on chemical composition but only *C. pallida*, *Z. fagara* and *F. angustifolia* showed nutritional favorable attributes: high content of crude protein (16%), low content of cell

wall (40% in *C. pallida* and *F. angustifolia*) and lignin (8% in *C. pallida* and *Z. fagara*), higher digestibility of dry matter (> 60%), higher content of digestible energy and metabolizable energy, mainly during winter and their low content of INDF. *C. pallida* yielded the highest nutrient values in this study, but it is not documented as preferred species by White-tailed deer, nevertheless, it could be valuable as emergency species. In general, all shrub species have low energy content to meet white-tailed deer requirements, but diversity in the habitat and therefore in the diet of the white-tailed deer is important. It is necessary to develop exhaustive research on the nutritional values of these species and the capacity of white-tailed deer to take advantage of them.

ESTRUCTURA DE LA TESIS

Para abordar los objetivos específicos y probar la hipótesis planteada se consideró la estructura de la tesis con el siguiente contenido: La primera sección es donde se describe el contexto, los objetivos e hipótesis. La segunda sección constituye aspectos relativos a la metodología general. De la tercera a la quinta sección fueron incluidos los productos de la presente investigación de acuerdo al formato de la revista donde fueron aceptados los manuscritos generados. En la tercera sección (manuscrito aceptado por la Revista Journal of Animal and Veterinary Advances) hace referencia al contenido de macro nutrientes estudiadas en cinco especies: *Castela erecta texana*, *Celtis pallida*, *Forestiera angustifolia*, *Lantana macropoda* y *Zanthoxylum fagara*, cuyos valores a lo largo de los dos años de estudio fueron correlacionados con los parámetros de precipitación y temperatura de los tres sitios de estudio. Para las mismas especies, el contenido de micro nutrientes fue tratado en la sección cuarta (manuscrito aceptado por la Revista Journal of Applied Animal Research). Los dos manuscritos están enfocados a conocer si las especies estudiadas cubren a lo largo del año los requerimientos mínimos de mantenimiento para el venado cola blanca y donde se pueden consultar los contenidos particulares por estación en cada sitio y para cada especie en la región.

Dentro de la quinta sección se encuentra el manuscrito (aceptado por la Revista Journal of Animal and Veterinary Advances) sobre las variables analizadas en las especies *Acacia amentacea*, *Castela erecta texana*, *Celtis pallida*, *Croton cortesianus*, *Forestiera angustifolia*, *Karwinskia humboldtiana*, *Lantana macropoda*, *Leucophyllum frutescens*, *Prosopis laevigata*, *Syderoxylon celastrinum* y *Zanthoxylum fagara* para evaluar la calidad nutritiva de los forrajes en su aporte de proteína cruda, fibra y energía metabolizable a la dieta del venado cola blanca texano, para la región noreste de México.

En la sexta sección se generaron las conclusiones generales, las cuales indican que las especies estudiadas ofrecen la mayoría de nutrientes requeridos al venado cola blanca para su mantenimiento y destaca que varias de las especies estudiadas, especialmente en temporada invernal podrían ser de valor para su mantenimiento en estas temporadas. El hecho de que varias especies en distintas estaciones del año proporcionen diferentes contenidos de nutrientes al venado cola blanca, destaca que la diversidad de plantas nativas es un punto importante en la nutrición del venado cola blanca, independientemente de las cualidades nutricionales que cada especie posee en lo individual.

1. INTRODUCCIÓN GENERAL

1.1. CONTEXTO

Las especies arbustivas juegan un papel importante en áreas con un largo periodo seco donde el forraje herbáceo es escaso en calidad y en cantidad para cubrir los requerimientos de los rumiantes. Las arbustivas por su alto valor nutritivo (proteína, vitaminas y minerales), diversidad, bajo costo y en algunos casos por ser preferidas por los rumiantes en pastoreo, son reconocidas como componentes importantes en la alimentación animal y son opción con gran potencial para su aplicación en rumiantes, especialmente bajo sistemas extensivos (Le Houerou, 2000; Ramírez *et al*., 2000; Parissi *et al*., 2005; Ramírez, 2009; Azim *et al*., 2011; Kökten *et al*., 2012).

Los árboles y arbustos forrajeros pueden ser útiles para mejorar las tierras de pastoreo donde la cobertura es pobre, como un banco de alimento para amortiguar las fluctuaciones estacionales, como un suplemento de proteína. Pueden significar un control a la erosión y ser una fuente de combustible para los habitantes de zonas rurales. En el sur de Europa, el Este de Asia y norte de África el pastoreo de rastrojo de cereales en verano (después de la cosecha de grano) y la subsecuente alimentación con paja son prácticas ampliamente usadas (Chriyaa, 2008).

En algunas regiones de Pakistán, durante la temporada seca y la de post cosecha, los granjeros tradicionalmente alimentan a su ganado con especies forrajeras nativas para cubrir los requerimientos de los animales en pastoreo. Las investigaciones revelaron que los follajes son una buena fuente de nutrientes (proteínas, grasas, carbohidratos, fibra y minerales) y pueden ser usados para el déficit de sustratos en cualquiera de estos nutrientes para los rumiantes en esas regiones en particular (Azim *et al*., 2011).

En México, los matorrales cubren alrededor del 40% de la superficie con vegetación (Rzedowski, 1981) y proporciona al humano el suministro energético, alimenticio, de diversos materiales para su vida. De forma excepcional para las regiones áridas y semiáridas, provee valor nutritivo y alimenticio (nitrógeno, energía, vitaminas y minerales) a los rumiantes domésticos y silvestres sobre todo en los largos periodos de sequía (Martínez y Dante, 1994; González y Cantú, 2001; Ramírez y González, 2010).

El matorral espinoso tamaulipeco es el principal tipo de vegetación en el noreste de México, compuesto de arbustos y árboles diversos, densos y espinosos, que se distinguen por un amplio rango de grupos taxonómicos mostrando diferencias en patrones de crecimiento, diversidad en la longevidad foliar, dinámicas de crecimiento y desarrollo fenológico (Ramírez y González, 2010). La eco región anteriormente mencionada tiene una amplia variedad de agostaderos, los cuales tradicionalmente han sido utilizados como una fuente de forraje para el pastoreo de animales domésticos y han sostenido un gran número de animales silvestres como el venado cola blanca texano (Ramírez, 2004).

El venado es considerado como ramoneador debido a que consume vegetación del matorral, aunque el venado prefiere las hierbas más que los arbustos, pero está obligado a consumir arbustivas cuando las plantas herbáceas no están presentes en el agostadero o declinan en calidad nutritiva. Existen varias causas para explicar la habilidad del venado por consumir forraje proveniente de árboles pequeños y arbustos como las explicaciones dadas por Fulbright y Ortega (2007) quienes señalan que el venado cola blanca y las plantas que consume evolucionaron conjuntamente, las plantas desarrollaron características que les permiten sobrevivir a pesar de ser consumidas y los animales se adaptaron a los cambios morfológicos de las plantas siendo así que el venado puede consumir mayor cantidad y a mayor velocidad algunas especies dependiendo del tamaño y constitución de las hojas y rebrotes y el hocico pequeño del venado cola blanca le puede permitir ramonear fácilmente a pesar de la presencia de espinas o tallos espinosos. Por otra parte, Makkar y Becker (1998) comentan que los venados muestran hipertrofia de la glándula salival incluida la secreción de proteínas ricas en prolina que blinda a los taninos (metabolitos secundarios de las plantas).

El venado siempre tratará de mantener una dieta de calidad, que cubra sus necesidades nutricionales, ajustando los componentes de la dieta conforme las plantas forrajeras cambian de calidad. Si uno o ambos factores, mencionados arriba, son limitantes, causarán un detrimento en la nutrición del venado (Richardson, 1999).

En la mayor parte de los predios del noreste de México, la disponibilidad de forraje no es, por lo general, un problema pues se han identificado 32 especies de plantas arbustivas consumidas por el venado cola blanca que son nativas de la flora de varios municipios de Nuevo León, México, pertenecientes al matorral Espinoso Tamaulipeco de la Planicie Costera del Golfo (Ramírez *et al*., 1997). Esta dieta es complementada con otras especies de herbáceas, zacates y cactáceas respectivamente, que en su conjunto ofrecen una dieta adecuada para el venado cola blanca (Villarreal González, 1999; Ramírez, 2004).

Una gran variedad de plantas en diferentes estados de crecimiento aumenta la probabilidad, durante todo el año, de disponibilidad de forrajes de alta calidad nutritiva. El venado puede cambiar los componentes de su dieta en respuesta a los cambios de los niveles de nutrientes asociados con el crecimiento estacional de cada especie. Los requerimientos nutricionales del venado cola blanca no se han estudiado objetivamente o no están bien documentados como es el caso de los rumiantes domésticos (Ramírez, 2004).

De acuerdo a Foroughbakhch *et al*. (2007) y Ramírez (2009) el valor nutritivo de un forraje es determinado por su composición química (contenido de macro nutrientes y micro nutrientes) y por la capacidad del animal de digerir y utilizar esos alimentos. La composición química es determinada por la naturaleza de la planta, sufre cambios conforme la planta madura y puede ser influida por las condiciones ambientales durante el crecimiento (fertilidad del suelo, estación, temperatura, iluminación, estrés hídrico, etc.). La digestibilidad del forraje es afectada por la madurez de la planta, aunque el ambiente puede modificarla. La temperatura, el déficit de agua, la radiación solar, la deficiencia de nutrientes y las plagas, son causas de estrés en la planta y la pared celular les provee la primera línea de defensa contra alguno de esos factores que causan estrés. En el desarrollo de la pared secundaria, la lignina es un importante componente de protección para la planta, aunque la lignificación restringe la disponibilidad de nutrientes de la pared celular para los animales que consumen los forrajes (Ramírez, 2009).

Jančík *et al*. (2008) explican que la digestibilidad está limitada por el grado de digestión de la pared celular debido a que una parte de ésta no se encuentra disponible para la digestión microbiana dentro del rumen incluso cuando se mantenga dentro por un periodo de tiempo infinito. Como consecuencia de la elongación celular y la diferenciación (debido a alteraciones sutiles de la estructura química de los componentes de la pared celular) los compuestos insolubles e indigestibles se incrementan en las células vegetales (Ramírez *et al*., 2002).

En base a lo anteriormente descrito y con el propósito de contribuir al conocimiento sobre el perfil nutricional de especies arbustivas del matorral espinoso tamaulipeco consumidas por el venado cola blanca, en este estudio se plantearon los siguientes objetivos e hipótesis:

1.2. OBJETIVO GENERAL

Caracterizar el perfil nutricional de once especies arbustivas nativas del matorral espinoso tamaulipeco que son reportadas en la literatura como parte de la dieta del venado cola blanca texano (*Odocoileus virginianus texanus*).

1.3. OBJETIVOS ESPECÍFICOS

1.3.1. Determinar el contenido de macro (Ca, K, Mg, Na y P) y micro nutrientes (Cu, Fe, Mn y Zn) en las especies: *Castela erecta texana*, *Celtis pallida*, *Forestiera angustifolia*, *Lantana macropoda* y *Zanthoxylum fagara*.

1.3.2. Determinar la composición química, el contenido de proteína, la digestibilidad y energía de las once arbustivas nativas del noreste de México y comprar los resultados entre las cuatro estaciones del año en un periodo de dos años y en tres sitios de muestreo; con ello se pretende establecer el valor nutricional potencial de las especies nativas consumidas por el venado cola blanca, de acuerdo a reportes previos en la literatura.

1.4. HIPÓTESIS GENERAL

Once especies arbustivas nativas consumidas por el venado cola blanca (*Odocoileus virginianus*) cubren los requerimientos nutricionales de esta especie en los sitios de estudio a lo largo del año.

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2. MATERIALES Y MÉTODOS

2.1. SITIOS DE ESTUDIO

El presente estudio se llevó a cabo en la provincia biótica llamada Matorral Espinoso Tamaulipeco o Matorral espinoso subtropical que se localiza al noreste de México en la provincia fisiográfica conocida como la Planicie Costera del Golfo, comienza en la parte Este del estado de Coahuila, en México en la base de la Sierra Madre Oriental y prosigue hacia el este hasta la mitad norte del Estado de Tamaulipas y dentro de los Estados Unidos a través del lado suroeste del Estado de Texas a lo largo de por lo menos 362 km entre la costa y los matorrales deciduos de la Sierra Madre Oriental a ambos lados del Río Grande en Texas y el noreste de México. La elevación se incrementa hacia el noroeste desde el nivel del mar en la costa del Golfo a la base de aproximadamente 300 metros cerca de la frontera de la ecoregión desde la cual pocas colinas o montañas sobresalen. Los arbustos espinosos y árboles dominan el paisaje pero también hay zacates, herbáceas y suculentas prominentes. Combinados los elementos del agostadero con los zacates como en la sabana y páramos, los arbustos leguminosos y árboles se incluyen en esta región. Todos juntos componen una tercera parte de diversidad leñosa, esta combinación particular es usada por los locales como pastizales para la ganadería intensiva, fuente de madera para la construcción y carbón (Everitt *et al*., 2002).

Los tres sitios de muestreo están localizados en el Estado de Nuevo León, México. El sitio 1 se ubicó en el Rancho “Zaragoza” en el municipio de China (25º 31´N y 99º 16´O) con una altitud de 200 m. El sitio 2 se localizó en la Estación Experimental de la Facultad de Ciencias Forestales de la Universidad Autónoma de Nuevo León, en el municipio de

Linares (24º 47´N; 99º 32´O; altitud de 350 m). El sitio 3 se situó en el Rancho "El Abuelo" en el municipio de Los Ramones (25º 40´N; 99º 27´O con altitud de 200 m). En general, los tres sitios están agrupados bajo un patrón climático similar, con una precipitación anual que varía de 650 a 800 mm con distribución bimodal (mayores precipitaciones en mayo-junio y agosto-septiembre). La temperatura media del aire de la región varía de 14.7 ºC en enero a 22.3 ºC en agosto, aunque las temperaturas diarias, durante el verano, pueden ser superiores a los 45 ºC (González *et al*., 2004). En los sitios Los Ramones y China no se han registrado actividades ganaderas en los últimos cinco años y el sitio 2 en los últimos 25 años. El principal tipo de vegetación del área es conocido como Matorral Espinoso Tamaulipeco o Matorral espinoso subtropical. Los suelos dominantes son profundos, gris-obscuro, vertisoles limo grisáceos, con montmorillonita (INEGI, 2002). Durante el primer año (verano de 2004 a la primavera de 2005) de estudio, la precipitación fue: sitio 1 = 649 mm, sitio 2 = 702 y sitio 3 = 759. Durante el segundo año (verano 2005 a la primavera de 2006) fue: sitio 1 = 898, sitio 2 = 962 y sitio 3 = 903.

2.2. MATERIAL VEGETAL

Las especies estudiadas fueron: *Acacia amentacea* DC. (Fabaceae), *Castela erecta* Turp. ssp. *texana* Torr. & A. Gray Cronquist (Simaroubaceae), *Celtis pallida* Torr (Ulmaceae), *Croton cortesianus* Kunth (Euphorbiaceae), *Forestiera angustifolia* Torr (Oleaceae), *Karwinskia humboldtiana* Roem. Et Schult (Zucc.) (Rhamnaceae), *Lantana macropoda* Torr. (Verbenaceae), *Leucophyllum frutescens* (Berl.) I.M. Jhonst. (Scrophulariaceae), *Prosopis laevigata* (Humb. & Bonpl. Ex Willd.) M.C. Jhonston. (Fabaceae), *Syderoxylon celastrinum* (Kunth) (Sapotaceae) y *Zanthoxylum fagara* (L.) Sarg. (Rutaceae). Estas especies son representativas de la vegetación nativa del noreste de

México y el ecosistema de sabana subtropical del sur de Texas, EE.UU. (Everitt et al., 2002). Estas especies son consumidas por el venado cola blanca y los rumiantes en pastoreo (Quintanilla, 1989; Moreno, 1991; Valdés, 1995; Molina, 1994; Olguín, 2005; Ramírez, 2004, 2009; Ramírez et al., 2010 a,b).

2.3. MUESTREO

Para colectar las hojas maduras (aproximadamente 800 g) de las especies a estudiar, se seleccionaron al azar 4 plantas de cada especie (Cochran, 1977), a la altura de ramoneo (1.20 m) se cortaron las hojas y ramillas de la parte media de la planta por la parte exterior de cada planta. Las plantas se encontraban dentro de una parcela representativa y sin disturbio de 50 m x 50 m localizada en cada sitio. Las colectas fueron realizadas durante dos años consecutivos: verano de 2004 (28 de agosto); otoño de 2004 (28 de noviembre); invierno de 2005 (28 de febrero); primavera de 2005 (28 de mayo); verano de 2005 (28 de agosto); otoño de 2005 (28 de noviembre); invierno de 2006 (28 de febrero) y primavera de 2006 (28 de mayo). Las muestras de hojas por especie fueron colocadas juntas dentro de bolsas de papel estraza y almacenadas para su transporte al laboratorio. Las muestras fueron secadas en estufa durante 24 horas a 60 °C, una vez que las muestras tuvieron un peso constante, fueron molidas a través de una malla de 1 mm en un molino T. Wiley.

2.4. ANÁLISIS DE MACRO NUTRIMENTOS

Muestras por cuadriplicado de cada especie de planta por muestreo fueron utilizadas para el análisis de minerales, mismos que fueron estimados por incineración en una mufla a 550 °C durante 5 horas. Las cenizas fueron digeridas en ácido clorhídrico (HCl) y ácido nítrico (HNO_3) usando la–técnica de digestión húmeda (Cherney, 2000). El contenido de

Calcio (Ca) y Magnesio (Mg) se determinaron con óxido nitroso / flama de gas acetileno. Los contenidos de potasio (K) y sodio (Na) fueron determinados por absorción atómica por espectrofotometría usando un espectrofotómetro de absorción atómica (modelo SpectrAA-200). El fósforo (P) fue cuantificado por medio de espectrofotometría usando un espectrofotómetro-UV-Visible (modelo Lambda 1A) Perking Elmer Corp., Analytical Instruments, Norwalk, CT, USA) de acuerdo a los procedimientos de la AOAC (2000).

2.5. ANÁLISIS MICRO NUTRIMENTOS

Muestras por cuadriplicado de cada especie de planta fueron empleados para el análisis de minerales que fueron estimados por incineración en una mufla a 550 °C durante 5 horas. Las cenizas fueron digeridas en ácido clorhídrico (HCl) y ácido nítrico (HNO_3) usando la técnica de digestión húmeda (Cherney, 2000). Los contenidos de Cobre (Cu), Fierro (Fe), manganeso (Mn) y Zinc (Zn) se determinaron con aire / flama de gas acetileno por espectrofotometría usando un espectrofotómetro de absorción atómica (modelo SpectrAA-200).

2.6. ANÁLISIS QUÍMICO

La materia seca parcial (MS) fue calculada mediante el secado de las muestras en una estufa a 55 °C durante 72 horas hasta peso constante, por triplicado. Las muestras fueron analizadas para materia orgánica y cenizas de acuerdo a los procedimientos de la AOAC (1995). De acuerdo a los procedimientos de AOAC (1997) se estimó el contenido de Cenizas Totales (CT) y la proteína cruda (PC) misma que fue estimada multiplicando el factor de conversión 6.25 por el contenido de nitrógeno total, mismo que fue obtenido por el método micro Kjeldahl. La fibra neutro detergente (FND), la fibra ácido detergente

(FAD) y lignina (L) fueron desarrollados de acuerdo a los procedimientos descritos por Van Soest *et al*. (1991). La Hemicelulosa (FND-FAD) y la celulosa (FAD-L) fue estimada por diferencia. Aunque el valor preciso de digestibilidad es objetivo, para obtener dichos datos se consume tiempo y recursos y requiere una muestra mayor de forraje por lo que no fue posible en este estudio. Por lo tanto, la digestibilidad de la materia seca (DMS %) fue estimada usando la fórmula desarrollada por Oddy *et al*. (1983): DMS = 83.58 – (0.824 x FAD%) + (2.626 x nitrógeno %). Los valores de la digestibilidad de materia seca fueron usados para estimar la energía digestiva (ED, kcal kg^{-1} MS) usando la ecuación de regresión de Fonnesbeck *et al*. (1984): ED = 0.27 + (0.0428 x DMS %). Posteriormente, los valores de ED fueron convertidos a Energía Metabolizable (EM, Mcal kg^{-1} MS) usando la ecuación propuesta por Khalil *et al*. (1986): EM = 0.821 x ED (kcal kg^{-1} MS). Las ecuaciones predictivas derivadas en este estudio podría ser usadas en estimar la digestibilidad de nutrientes y energía si la composición química relevante es conocida sin realizar costosos experimentos sobre alimentos (Appiah *et al*., 2012). La fibra neutro detergente insoluble (FNDI, g kg^{-1} MS) fue calculada mediante la ecuación desarrollada por Jančík *et al*. (2008): FNDI = –86.98 + (1.542 x FND %) + (31.63 x L %).

2.7. ANÁLISIS ESTADÍSTICOS

Los datos fueron analizados estadísticamente usando un diseño completamente al azar con un arreglo trifactorial donde los factores fueron años (A, 2), sitios de muestreo (B, 3) y estaciones (C, 4) y con tres repeticiones. Asimismo, se realizaron análisis de correlación Pearson entre la composición mineral de las hojas y precipitación registradas durante el estudio. Los análisis estadísticos se llevaron a cabo con el paquete computacional SPSS de

Windows versión 13 (SPSS, 2000). Las diferencias entre medias fueron calculadas usando la prueba de Tukey (P=0.05).

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3. MACRO MINERAL CONTENT IN FIVE SHRUBS BROWSED BY WHITE-TAILED DEER (*Odocoileus virginianus*), NORTHEASTERN MEXICO[1]

3.1. ABSTRACT

Developed from the hypothesis that browse plants, natives from the northeastern Mexico, contain essential macro minerals in sufficient amounts to meet nutritional requirements of white-tailed deer, the Ca, K, Mg, Na and P contents were determined, seasonally, during two consecutive years. Pearson correlation coefficients were performed between mineral content with rainfall and temperature registered during the two-year study. Leaves of native browse plants such as *Castela erecta* Turp spp. Texana (Torr & A. Gray) Cronquist (Simaroubaceae), *Celtis pallida* Torr. (Ulmaceae), *Forestiera angustifolia* Torr. (Oleaceae), *Lantana macropoda* Torr. (Verbenaceae) and *Zanthoxylum fagara* (L.) Sarg (Rutaceae) were collected from August 2004 to May 2006 in a semiarid and subtropical area of the State of Nuevo Leon, Mexico at three county (Los Ramones, China and Linares) sites, which are grouped under a similar climatic pattern. Mineral contents were measured using an atomic absorption spectrophotometer, with exception of P content that was estimated using a colorimeter. All minerals, in all species, were significantly different among years, sites and seasons and interactions were also significant. In general, plants at Linares site, which historically shows highest rainfall, had higher mineral content followed by Los Ramones and China. Moreover, during the second year, all plants species showed

[1] Este manuscrito fue redactado de acuerdo a las reglas editoriales de la revista Journal of Animal and Veterinary Advances (www.medwelljournals.com/journalhome.php?jid=1680-5593).

higher mineral content than the first year. Furthermore, during the summer season, all plants species had higher mineral content followed by autumn, winter and spring. Regardless of spatio-temporal differences, all plant species had suitable levels of Ca, Mg and K to satisfy range domestic and wild ruminant requirements. In contrast, P and Na contents showed marginal inadequacies in some seasons throughout the year. Seasonal variations in minerals could be associated to climatic conditions like excessive irradiance levels during summer and extreme low temperatures in winter and rainfall events.

3.2. INTRODUCTION

The Tamaulipan Thornscrub or Subtropical Thornscrub is located at northeastern Mexico in the physiographical province known as the Coastal Gulf Plain. It begins in the eastern part of the Coahuila State, in Mexico at the base of the Sierra Madre Oriental, and then proceeds eastward to encompass the northern half of the state of Tamaulipas, and into the United States through the south western side of Texas. Elevation increases northwesterly from sea level near the Gulf Coast to a base of about 300 m near the northern boundary of the ecoregion, from which a few hills or mountains protrude (Everitt *et al*. 2002).

The following native shrubs that are growing in the Tamaulipan Thornscrub or Subtropical Thornscrub Woodlands of northeastern Mexico: 1) *Castela erecta* Turp spp. Texana (Torr & A. Gray) Cronquist (Simaroubaceae), 2) *Celtis pallida* Torr. (Ulmaceae), 3) *Forestiera angustifolia* Torr. (Oleaceae), 4) *Lantana macropoda* Torr. (Verbenaceae) and 5) *Zanthoxylum fagara* (L.) Sarg (Rutaceae) (Everitt *et al*., 2002) are important feed resources for range ruminants and white-tailed deer (Ramírez, 1999; Olguín, 2005;

Ramírez, 2004, 2009). They also provide high quality fuel wood and timber for fencing and construction, and are widely distributed in combination with other species (scattered), or are found in pure stands (Fulbright and Ortega, 2006). However, they are affected by climatic conditions and probably causing differences in the concentrations of macro and trace minerals when considering effects in space (sites) and weather (seasonality).

Range livestock and white-tailed deer need macro minerals for skeletal growth, milk production, and the maintenance of body fluids mainly. The concentration of minerals in plants is dependent upon interactions among a number of factors including soil type, plant species, stage of maturity, dry matter yield, grazing management and climate. Besides, it has been documented that environmental factors such as temperature and rainfall, influence on mineral content in shrubs (Ramírez *et al*., 2010). Although the concentration of a mineral in the forage is important, the biological availability of the mineral is equally important. Biological availability (absorption and utilization) of minerals varies substantially among animal species and breeds within a species, as well as among forages. The combination of all of these factors makes it extremely difficult for range nutritionists to determine mineral status of the range ruminant animal.

The aims of this study were to determine and compare, seasonally, throughout two consecutive years, Ca, K, Mg, Na and, P contents of five native plants that are consumed by white-tailed deer. Objectives were developed from the hypothesis that browse plants, growing in northeastern Mexico, contain essential minerals in sufficient amounts to meet the nutritional requirements of white-tailed deer.

3.3. MATERIAL AND METHODS

This study was carried out at three sampling sites situated in the state of Nuevo Leon, northeastern Mexico. The first site was located at “El Abuelo” ranch in Los Ramones county (25º 40' N; 99º 27' W) with an elevation of 200 m. The second site was located at the Campus of the Facultad de Ciencias Forestales, Universidad Autonoma de Nuevo Leon (24º 47' N; 99º 32' W; elevation of 350 m) located at Linares county. The third site was located at “Zaragoza” ranch in China county (25º 31' N; 99º 16' W). It has an elevation also of 200 m. Vegetation of the three sites is composed by browse plants that are consumed by range livestock (cattle, sheep and goats) and wildlife (white-tailed deer), and is representative of the central region of the state of Nuevo Leon.

The main native vegetation type covering much of the northeastern region of Mexico and parts of southern Texas is mesquite-grassland, an important element of the ecoregion that plant ecologists classify as characteristic of the Tamaulipan biotic province. The Tamaulipan province extends south of the border for almost 362 km between the coast and the deciduous woodlands on the slopes of the Sierra Madre Oriental. The Tamaulipan thornscrub, a subtropical, semi-arid vegetation type, occurs on either side of the Rio Grande, Texas, USA and northeastern Mexico. Spiny shrubs and trees dominate this thornscrub, but grasses, forbs, and succulents are also prominent. This region also includes elements of the range, a combination of grassland, savanna, and paramo-like communities. Leguminous shrubs and trees constitute one-third of the diverse woody flora, which the rural population uses for extensive grazing of livestock, fuelwood, and timber for fencing and construction (Everitt *et al*., 2002).

In general, the three sites used in this study are grouped under a similar climatic pattern (subtropical and semiarid with warm summer) with an annual precipitation that ranges from 650 to 800 mm with a bimodal distribution (peaks rainfall are during May, June and August, September). Monthly mean air temperature of the region ranges from 14.7^{o} C in January to 22.3^{o} C in August, although daily high temperatures of 45^{o} C are common during summer (González *et al*., 2004). Los Ramones and China sites have not registered livestock activities in the last five years, and Linares since the last 25 years. In this study, seasonal rainfall and mean air temperature registered at each site are shown in Table 3.1. The main type of vegetation of the area is known as the Tamaulipan Thornscrub or Subtropical Thornscrub Woodlands (INEGI, 2002). Dominant soils are deep, dark-gray, lime-gray, lime-clay Vertisols, with montmorillonite, which shrink and swell noticeably in response to changes in soil moisture content.

Plant species such *Castela erecta* Turp spp. Texana (Torr & A. Gray) Cronquist (Simaroubaceae), *Celtis pallida* Torr. (Ulmaceae), *Forestiera angustifolia* Torr. (Oleaceae), *Lantana macropoda* Torr. (Verbenaceae) and *Zanthoxylum fagara* (L.) Sarg (Rutaceae) are representative of the native vegetation of the northeastern Mexico and the subtropical savanna ecosystems of southern Texas, USA (Everitt *et al*., 2002) and are consumed by range ruminates and white-tailed deer (Olguín, 2005; Ramírez, 2004, 2009). Terminal shoots with fully expanded leaves were randomly chosen from a 50 m x 50 m representative and undisturbed Thornscrub plot located in each site. Collections were undertaken, seasonally during two consecutive years: summer, 2004 (August 28); fall, 2004 (November 28); winter, 2005 (February 28); spring, 2005 (May 28); summer, 2005 (August 28); fall, 2005 (November 28); winter, 2006 (February 28) and spring, 2006 (May 28).

Shoots were excised and sampled (about 800 g) from the middle side of four plants (replications) of each species. Leaves were placed into paper bags and stored; then samples were transferred to laboratory for mineral analyses.

Quadruplicate samples of each plant species were used for analyses. Partial dry matter (DM) was determined subjecting samples to an oven and dried at 55 °C for 72 h. Then, samples were ground in a Wiley mill (1 mm) and stored in plastic containers for further analyses. Mineral content was estimated by incinerating samples in a muffle oven at 550 °C, during 5 hours. Ashes were digested in a solution containing HCl and HNO_3, using the wet digestion technique (Cherney, 2000). Contents of Ca and Mg (oxide nitrous/acetylene flame), K, Na, were determined by atomic absorption spectrophotometry using a Varian spectrophotometer (model SpectrAA-200); whereas, P was quantified spectrophotometrically using a Perkin-Elmer spectrophotometer (model Lamda 1A; Perkin-Elmer Corp., Analytical Instruments, Norwalk, CT, USA) (AOAC, 2000). Mineral data were statistically analyzed using one-way analysis of variance with a multi-factorial arrangement being years (2), sites (3), seasons (4), and plant species (5) the factors. All applied statistical methods were computed using the SPSS package (Version 9).

3.4. RESULTS AND DISCUSSION

All browse species had Ca, P, Mg, K and Na contents that were significantly different among sites, years and seasons. The interactions: site*year, site*season, year*season and site*year*season were also significant ($P<0.001$). In general, in Linares site showed the highest rainfall (Table 3.1) and highest macro mineral content. Except for *C. erecta,* all shrub species during second year and summer season had the highest values. Moreover, China site, during the second year and during winter season, had the lowest values.

3.4.1. Content of Calcium

The Ca content was higher in *C. pallida* (total mean = 50.9 g kg^{-1} DM) and *C. erecta* (24.3 g kg^{-1} DM) was lower (Table 3.2). During the wet seasons (summer and autumn) of both years, with higher temperatures, the mineral content was higher compared to dry seasons. Rainfall ($r = 0.65$; $P<0.001$) and temperature ($r = 0.69$; $P<0.001$) registered during the two-year study were positively correlated to Ca content in all plants. Seasonal inter species variation that occurred in this study, was also reported by Grenne *et al*. (1987). In this study, in spite of space - temporal differences, it appears that evaluated plants had substantial amounts of Ca, throughout the year, to sustain requirements of adult range white-tailed deer (4.5 g kg^{-1} of diet DM; NRC, 2007). In addition, Barnes *et al*. (1990) in south Texas, USA, and Ramirez *et al*. (2001), Cerrillo *et al*. (2004), Ramírez *et al*. (2005), Ramírez *et al*. (2006), Haenlein and Ramírez (2007), Guerrero (2009) and Ramírez *et al*. (2010) in north Mexico, reported that native shrubs and trees growing in semiarid and tropical regions had enough Ca for optimal white-tailed deer performance. High pH in the soils of these regions may be the cause why shrubs are high in Ca content (Spears, 1994). Most plants in this study had Ca content above 16 g kg^{-1} DM. Meeting Ca requirements is seldom a problem under grazing or browsing conditions with free-ranging white tailed deer (Whitehead, 2000).

3.4.2. Content of Phosphorous

All species had P content that varied from 1.6 to 2.1 g kg^{-1} DM (Table 3.3). Similar ranges were reported by Barnes *et al*. (1990) (1.5-2.8), Ramírez *et al*. (2001) (1.4-2.6) and Moya *et al.* (2002) (1.5-2.2). However, a higher range (2.0 to 4.0 kg^{-1}) was documented by Guerrero (2009) in native shrubs growing in north Mexico. In this study, most plants, in all sites, years and seasons, had P contents that were not sufficient to meet adult white-tailed deer (2.8 g kg^{-1} DM; NRC, 2007), especially during dry seasons (winter and spring).

In this study, rainfall ($r = 0.65$; $P<0.001$) and temperature ($r = 0.68$; $P<0.001$) registered during the two-year study were positively and significantly related to P content in all plants. During the wet seasons, of both years, with higher temperatures (summer and autumn), the mineral content was higher compared to dry seasons. Low P and high Ca contents resulted in an unusually wide Ca:P ratio (from 9:1 to 22:1). Similarly, a wide range in Ca:P ratio have been reported by Kallah *et al*. (2000). However, it seems that the browsing of small ruminants (goats, sheep and white-tailed deer) can sustain these high Ca:P ratios without being affect their P metabolism (Ramírez, 1999).

However, in some situations osteodystrophis fibrous caused by feeding with a high ratio of Ca:P, results in decalcification of bones and a progressive swelling of facial bones. Often land-owner increases the grain supplements in the diet with the believe of speeding the young animal´s growth (McDowell, 2003). Meanwhile, excesses of P may cause blockage of the urinary system by stones. This occurs in animals fed with concentrates but not in those fed on shrubby vegetation and other forages. If concentrates may be required, calcium chloride can be added to correct the Ca:P ratio (Underwood and Shuttle, 1999).

3.4.3. Content of Magnesium

The Mg content (Table 3.4) was higher in *C. pallida* (total mean = 7 g kg^{-1} DM) and lower in *C. erecta* and *Z. fagara* (3.2 g kg^{-1} DM). The Mg content in all plants augmented as rainfall (r = 0.69; P<0.001) and temperature (r = 0.64; P<0.001) increased, being summer and autumn, of both years, higher than winter and spring. It seems that all studied plants, in all seasons, had Mg contents to meet adult white-tailed deer of 1.0 g kg^{-1} DM (NRC, 2007). Barnes *et al*. (1990) reported a very similar range (1.1 to 8.0 g kg^{-1} DM) in 18 shrubs that growth in Texas, USA.

Moreover, other studies have found that diets, from esophageal samples by range goats growing in north Mexico (Cerrillo *et al*., 2004), or browse plants from northeastern (Ramírez *et al*., 2001; Moya *et al*., 2002; Ramírez *et al*., 2006) and northwestern (Ramírez *et al*., 2005) Mexico had sufficient amounts of Mg to meet requirements of adult small ruminants. Magnesium deficiency is associated with hypomagnesemic tetany (grass tetany), but ordinarily this condition is less common in range small ruminant than in cattle. Goats and white-tailed deer have marginal ability to compensate for low magnesium by decreasing the amount of magnesium they excrete. Both urinary excretion and milk production are reduced in a magnesium deficiency (McDowell, 2003).

3.4.4. Content of Potassium

During summer all plants had higher K than in other seasons (Table 3.5), particularly was higher in *L. macropoda* (21 g kg^{-1} DM) and lower in *C. erecta* (7 g kg^{-1} DM). Seasonal variation in K content might be related to water availability, because K absorption by the root is linked to the soil moisture (McDowell, 2003). It seems that adult range white-tailed deer consuming these plants could acquire substantial amounts of K to meet their requirements of K in all seasons (6.0 g kg^{-1} DM; NRC, 2007).

Similar findings were reported to ruminants by Greene *et al*. (1987), Ramírez *et al*. (2001), Moya *et al*. (2002), Cerrillo *et al*. (2004), Ramírez *et al*. (2005), Ramírez *et al*. (2006), and Guerrero (2009) who evaluated K content in browse species growing in arid and semiarid regions of the world. Considering all required minerals, K is most affected by forage maturity. Young actively growing forage may contain excess K in the range of 4-5 %, while mature forages are often less than 0.4-0.5 %. Potassium in milk is not affected by diet, season or stage of lactation; this is generally true for all macro minerals (McDowell, 2003). The main reason for lack of widespread K deficiency, even when forages contain lower than the minimum requirements, is likely due to the deficiencies of other nutrients in forages. It is expected that K deficiency will not be expressed as long as there are other nutrients that are even more deficient (McDowell and Valle, 2000).

3.4.5. Content of Sodium

Sodium content (Table 3.6) resulted higher in *F. angustifolia* (2.0 g kg^{-1} DM) and lower in *C. erecta* (1.7 g kg^{-1} DM). It appears that most plants can be considered as Na non-accumulators because they contain less that 2.5 g kg^{-1} DM (Youssef, 1988). In this study, rainfall ($r = 0.70$; $P<0.001$) and temperature ($r = 0.74$; $P<0.001$) influenced Na content in all plants. During all seasons most plants had Na content to meet the needs of white-tailed deer (1.0 g kg^{-1} DM; NRC, 2007).

High K content (range = 7-21 g kg^{-1} DM) in studied plants could reduce Na absorption of range ruminants feeding with these plants since it has been reported that elevated dietary in K may decrease ruminal concentration and absorption of Na in sheep and steers (Spears, 1994). In this study, all evaluated shrubs had Na contents that increased as rainfall ($r = 0.66$; $P<0.001$) and temperature ($r = 0.67$; $P<0.001$) augmented.

Salt (NaCl) is usually recognized as a necessary dietary component but is often forgotten. Range small ruminants may consume more salt than is required when it is offered *ad libitum*; this does not present a nutritional problem but may depress feed and water intakes in some arid regions where salt content of the drinking water is quite high. Salt formulations are used as carriers of trace minerals, as range ruminants have a clear drive for sodium intake. Lactating ruminants often requires additional salt as milk contains high amounts of Na (Whitehead, 2000).

3.5. CONCLUSIONS

The macro mineral content in the five shrubs studied in Tamaulipan Thornscrub is sufficient to meet the white-tailed deer requirements all year around while P contents were deficient in most seasons. Most plants had higher levels of the determined minerals during summer and autumn when rainfall and temperature were high.

In this study, rainfall and temperature influenced positively mineral content. Low rainfall and temperature, which occurred during winter and spring, affected mineral content in evaluated plants.

Diet formulation for range white-tailed deer should include an evaluation of the availability of dominant plants and concerns of their probable mineral contents during certain seasons for ration formulation should be considered. Thus, results of the present study may suggest that, even though all plants differed in mineral content and followed a seasonal pattern, during adequate or adverse conditions such as extreme temperatures and water shortages, they still could play important roles in maintaining the productivity of dry rangeland ecosystems.

The higher mineral content in all plants during the second year of the study may be explained by the fact that the Hurricane Emily occurred in the region registering more rainfall during the summer and autumn of 2005 that the previous year.

In addition, higher mineral content at the Campus site (undisturbed during the last 25 years) may be related to the higher historical precipitation (600-800 mm) compared to other sites (400-600 mm). Thus, the positive relationships between mineral content and seasonal mean temperatures and rainfall, reflects the plasticity of how native trees and shrubs species deal with seasonal water deficits, extreme temperatures (frost or heat) and excessive irradiance levels as main multiple abiotic stresses that may co-occur either during the dry or wet seasons.

Although shrubs and fodder trees are available and can provide feed of high nutritional value, especially during droughts to livestock in small and self-subsistence farms, they are underused in many countries of the world. This may be related to unawareness of the potential of tree and shrub species. To enrich the use of shrub and tree fodders, more information of species adaptation is needed. Thus, appropriated shrub and tree species can be chosen for different environmental conditions.

3.6. ACKNOWLEDGEMENTS

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Table 3.1. Environmental conditions registered from summer 2004 to spring 2006 at research sites, northeastern Mexico.

Season	Year	Site					
		Los Ramones		Linares		China	
		T(°C)	Rainfall (mm)	T(°C)	Rainfall (mm)	T(°C)	Rainfall (mm)
Summer 2004	1	23.6	457	23.6	447	22.8	429
Autumn 2004		19.4	131	22.1	97	17.7	96
Winter 2005		11.3	31	13.4	35	10.1	28
Spring 2005		18.2	140	20.5	123	16.5	96
Total rainfall			759		702		649
Summer 2005	2	24.5	486	23.4	465	23.1	422
Autumn 2005		19.5	301	19.2	316	17.2	294
Winter 2006		11.5	14	9.7	9.0	8.7	24
Spring 2006		19.9	102	19.6	172	18.8	158
Total rainfall			903		962		898

Table 3.2. Seasonal means of Ca content (g kg^{-1} DM) in native plants from northeastern Mexico.

Sites	Seasons	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
Los Ramones	Summer 2004	26.5	52.4	25.2	38.5	27.9
	Autumn 2004	30.8	50.6	24.2	36.4	25.6
	Winter 2005	29.5	48.4	22.5	34.2	24.2
	Spring 2005	24.7	46.4	20.6	31.6	20.2
	Summer 2005	24.9	54.6	26.6	39.2	29.7
	Autumn 2005	16.1	52.4	24.2	37.2	28.2
	Winter 2006	21.4	49.6	22.4	35.6	25.6
	Spring 2006	22.4	38.2	21.2	32.1	21.0
Linares	Summer 2004	25.7	58.3	28.6	41.1	36.2
	Autumn 2004	22.9	56.4	26.4	39.6	32.3
	Winter 2005	22.3	54.2	24.2	38.4	28.5
	Spring 2005	28.7	50.3	23.6	36.5	27.2
	Summer 2005	25.7	63.2	29.2	43.2	38.6
	Autumn 2005	23.2	60.1	27.6	40.6	32.4
	Winter 2006	24.9	57.6	25.6	39.4	29.5
	Spring 2006	22.4	55.4	24.1	37.1	26.5
China	Summer 2004	20.4	54.2	26.2	40.2	30.2
	Autumn 2004	29.4	52.6	25.1	37.2	27.5
	Winter 2005	22.0	49.4	23.2	35.4	25.6
	Spring 2005	22.8	37.6	21.4	32.1	24.2
	Summer 2005	31.8	55.6	27.2	41.4	31.2
	Autumn 2005	25.5	53.2	25.6	38.6	28.6
	Winter 2006	17.1	51.3	23.1	36.5	27.2
	Spring 2006	22.8	20.4	22.2	34.2	25.6
	Grand Mean	24.3	50.9	24.6	37.3	28.1
	SEM	1.0	0.6	0.1	0.2	0.3
	Effects	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	0.01	<0.001	<0.001
	Site (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Season (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	0.7	0.05	0.9	0.63	0.7
	A x C	<0.001	<0.001	<0.001	<0.001	0.001
	B x C	<0.001	<0.001	0.93	<0.001	<0.001
	A x B x C	<0.001	<0.001	0.01	<0.001	0.01

SEM = standard error of the mean; n = 4; *P* = probability.

Table 3.3. Seasonal means of P content (g kg^{-1} DM) in native plants from northeastern Mexico.

Sites	Seasons	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
Los Ramones	Summer 2004	1.7	1.9	1.8	2.1	2.2
	Autumn 2004	1.4	1.5	1.6	1.9	1.9
	Winter 2005	1.3	1.3	1.5	1.6	1.8
	Spring 2005	1.2	1.1	1.4	1.4	1.6
	Summer 2005	2.0	2.1	1.9	2.2	2.3
	Autumn 2005	1.8	1.9	1.8	1.9	2.1
	Winter 2006	1.3	1.6	1.7	1.8	1.9
	Spring 2006	1.2	1.4	1.6	1.6	1.8
Linares	Summer 2004	1.9	2.4	2.1	2.6	2.6
	Autumn 2004	1.8	2.2	1.9	2.4	2.3
	Winter 2005	1.6	2.0	1.8	1.8	2.0
	Spring 2005	1.4	1.9	1.7	1.6	1.9
	Summer 2005	2.3	2.8	2.3	3.7	2.7
	Autumn 2005	2.0	2.5	2.1	2.9	2.4
	Winter 2006	1.8	2.3	1.9	2.5	2.1
	Spring 2006	1.5	2.0	1.8	2.1	2.0
China	Summer 2004	1.7	2.0	1.9	2.2	2.2
	Autumn 2004	1.6	1.6	1.8	1.9	2.0
	Winter 2005	1.3	1.4	1.6	1.8	1.9
	Spring 2005	1.3	1.2	1.5	1.6	1.7
	Summer 2005	1.9	2.2	2.0	2.3	2.4
	Autumn 2005	1.7	1.8	1.8	2.1	2.2
	Winter 2006	1.4	1.7	1.7	1.9	2.0
	Spring 2006	1.4	1.5	1.6	1.7	1.8
	Grand Mean	1.6	1.9	1.8	2.1	2.1
	SEM	0.02	0.02	0.01	0.02	0.01
	Effects	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	<0.001	<0.001	<0.001
	Site (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Season (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001

SEM = standard error of the mean; n = 4; *P* = probability.

Table 3.4. Seasonal means of Mg content (g kg^{-1} DM) in native plants from northeastern Mexico.

Sites	Seasons	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
Los Ramones	Summer 2004	4.8	7.4	5.1	4.1	3.1
	Autumn 2004	3.6	7.0	4.3	3.9	2.9
	Winter 2005	3.0	5.8	3.5	3.7	2.7
	Spring 2005	3.4	4.4	2.9	3.5	2.5
	Summer 2005	3.1	7.6	5.5	4.5	3.2
	Autumn 2005	2.6	7.3	4.7	4.1	2.9
	Winter 2006	2.8	6.5	3.8	3.8	2.8
	Spring 2006	2.5	5.6	3.2	3.6	2.4
Linares	Summer 2004	3.5	8.4	5.7	5.9	3.6
	Autumn 2004	3.4	7.6	5.2	4.6	3.5
	Winter 2005	3.2	6.9	4.8	4.1	3.2
	Spring 2005	3.1	6.2	4.3	3.8	3.0
	Summer 2005	3.9	9.6	6.5	6.1	4.5
	Autumn 2005	3.7	8.2	5.9	5.6	3.9
	Winter 2006	3.4	7.2	5.3	4.8	3.6
	Spring 2006	3.2	6.9	4.6	4.2	3.4
China	Summer 2004	3.2	7.7	5.2	5.6	3.6
	Autumn 2004	3.1	7.2	4.6	4.6	3.3
	Winter 2005	2.8	6.2	3.7	3.8	2.7
	Spring 2005	2.9	6.1	3.2	3.6	2.6
	Summer 2005	4.1	7.8	5.6	5.8	3.6
	Autumn 2005	3.6	7.5	4.8	5.4	3.1
	Winter 2006	3.1	6.8	3.9	4.8	2.9
	Spring 2006	2.8	5.8	3.3	3.8	2.6
	Grand Mean	3.2	7.0	4.6	4.5	3.2
	SEM	0.04	0.1	0.02	0.02	0.02
	Effects	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	<0.001	<0.001	<0.001
	Site (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Season (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001

SEM = standard error of the mean; n = 4; *P* = probability.

Table 3.5. Seasonal means of K content (g kg^{-1} DM) in native plants from northeastern Mexico.

Sites	Seasons	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
Los Ramones	Summer 2004	7	18	21	22	12
	Autumn 2004	7	14	19	21	11
	Winter 2005	5	12	17	18	10
	Spring 2005	6	10	15	17	10
	Summer 2005	7	19	22	22	13
	Autumn 2005	7	17	20	21	13
	Winter 2006	6	15	17	19	12
	Spring 2006	5	13	16	17	10
Linares	Summer 2004	9	20	24	25	16
	Autumn 2004	8	17	20	23	15
	Winter 2005	8	15	18	21	14
	Spring 2005	7	14	17	19	13
	Summer 2005	9	22	25	26	18
	Autumn 2005	8	20	23	24	17
	Winter 2006	7	18	21	21	14
	Spring 2006	7	16	19	21	14
China	Summer 2004	7	19	21	22	14
	Autumn 2004	7	15	20	21	13
	Winter 2005	6	13	17	20	11
	Spring 2005	6	11	16	17	10
	Summer 2005	8	20	23	24	15
	Autumn 2005	7	18	20	22	14
	Winter 2006	7	16	19	20	13
	Spring 2006	6	14	17	18	12
	Grand Mean	7	16	20	21	13
	SEM	0.1	0.2	0.1	0.1	0.3
	Effects	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	<0.001	<0.001	<0.001
	Site (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Season (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001

SEM = standard error of the mean; n = 4; *P* = probability.

Table 3.6. Seasonal means of Na content (g kg^{-1} DM) in native plants from northeastern Mexico.

Sites	Seasons	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
Los Ramones	Summer 2004	2.2	1.6	2.1	1.8	1.9
	Autumn 2004	2.1	1.5	1.9	1.7	1.7
	Winter 2005	1.5	1.4	1.7	1.6	1.5
	Spring 2005	1.4	1.3	1.5	1.2	1.4
	Summer 2005	1.4	1.8	2.2	1.9	2.0
	Autumn 2005	1.3	1.6	2.0	1.7	1.8
	Winter 2006	1.6	1.5	1.8	1.7	1.6
	Spring 2006	1.3	1.4	1.6	1.4	1.5
Linares	Summer 2004	3.2	2.7	2.4	2.7	2.5
	Autumn 2004	2.9	2.5	2.2	2.6	2.3
	Winter 2005	1.3	2.2	2.0	1.8	1.9
	Spring 2005	1.7	2.1	1.8	1.7	1.7
	Summer 2005	3.1	2.8	2.6	2.9	2.6
	Autumn 2005	2.8	2.6	2.4	2.7	2.5
	Winter 2006	1.4	2.3	2.1	1.9	2.2
	Spring 2006	1.6	2.2	1.9	1.7	1.9
China	Summer 2004	1.8	1.7	2.2	1.9	2.1
	Autumn 2004	1.7	1.6	2.0	1.8	1.8
	Winter 2005	1.5	1.5	1.8	1.6	1.6
	Spring 2005	1.2	1.4	1.6	1.3	1.5
	Summer 2005	1.8	1.9	2.3	2.0	2.2
	Autumn 2005	1.7	1.7	2.2	1.8	2.0
	Winter 2006	1.2	1.6	2.0	1.5	1.8
	Spring 2006	1.1	1.5	1.7	1.4	1.7
	Grand Mean	1.7	1.9	2.0	1.8	1.9
	SEM	0.2	0.1	0.1	0.1	0.2
	Effects	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	<0.001	<0.001	<0.001
	Site (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Season (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001

SEM = standard error of the mean; n = 4; *P* = probability.

4. TRACE ELEMENTS IN NATIVE SHRUBS CONSUMED BY WHITE-TAILED DEER (*Odocoileus virginianus*) AT NORTHEASTERN MEXICO[2]

4.1. ABSTRACT

During two consecutive years, the trace elements (Cu, Fe, Mn, and Zn) were determined, seasonally in leaves of native shrub plants browsed by the white-tailed deer (*Odocoileus virginianus texanus*) in Tamaulipan Thornscrub vegetation of the State of Nuevo Leon, Mexico. Between summer 2004 and spring 2006 were collected *Castela erecta, Celtis pallida, Forestiera angustifolia, Lantana macropoda* and *Zanthoxylum fagara* in three study sites (Los Ramones, China, y Linares, NL, Mexico). Mineral contents were measured using an atomic absorption spectrophotometer. All minerals, in all species, were significantly different among years, sites and seasons and interactions. In general, plants in Linares site, that had the highest rainfall had higher mineral content; Moreover, during the year two, all plants species had higher mineral content; furthermore, during summer all plants had higher mineral content. Regardless of spatio-temporal differences, all plant species had suitable levels of Fe and Mn to satisfy range domestic and wild ruminant requirements. Nonetheless Cu presented concentrations in summer and autumn to meet requirements of small ruminants but not to white-tailed deer, while Zn showed marginal inadequacies in some seasons throughout the year. Seasonal variations in minerals could be associated to soil water deficits, excessive irradiance levels during summer and extreme

[2] Este manuscrito fue redactado de acuerdo a las reglas editoriales de la revista Journal of Applied Animal Research (http://www.tandfonline.com/toc/taar20/current).

low temperatures in winter that could have affected leaf development and mineral concentrations.

4.2. INTRODUCTION

The Tamaulipan Thornscrub or Subtropical Thornscrub vegetation represents a region of 200,000 km^2 located in northeastern Mexico in the physiographical province known as the Coastal Gulf Plain. It begins in the eastern part of the Coahuila State, in Mexico at the base of the Sierra Madre Oriental, and then proceeds eastward to encompass the northern half of the state of Tamaulipas, and into the United States through the south western side of Texas (Everitt et al. 2002). Regionally it is recognized as an important supplier of forage, charcoal, timber, food, medicines, herbal and seeds to reforestation with native species in northeast Mexico at the same time it does play an important role in the hydrological cycle and as a wildlife habitat (González and Cantú 2001). This region is considered suitable for developing domestic range livestock (goat, sheep and cattle) and wildlife such as the white-tailed deer, which is the native wild ruminant economically most valued by ranchers and farmers for game purposes in southern Texas and in the northeastern region of Mexico (Iqbal et al. 2004; Gallina et al. 2005).

These semiarid rangelands often do not provide an optimal diet throughout the year, especially the mineral supply because the concentration of minerals in plants depends on the interactions between soil, plant species, stage of maturity, dry matter production, grazing management and climate. The shrub consumption during the dry season is important because the drought makes herbaceous vegetation turn scarce and low quality to meet the requirements of ruminants (Le Houerou 2000; Parissi et al. 2005). The aims of this study were to determine and compare, seasonally, throughout two consecutive years the Cu, Fe, Mn and Zn contents of five native plants that are consumed by range ruminants. Objectives were developed from the hypothesis that browse plants, growing in northeastern Mexico, contain essential microminerals in sufficient amounts to meet requirements of adult range white-tailed deer.

As it is well documented, these micronutrients are involved in diverse biochemical processes such as respiration, activators of enzymatic systems and constituents of organic compounds (Ramírez 2004).

4.3. PROCEDURES

This study was carried out at three sampling sites located in the state of Nuevo Leon, Mexico. The first site was located at “El Abuelo” ranch in Los Ramones county (25º 40' N; 99º 27' W) with an elevation of 200 masl. The second site was located at “Zaragoza” ranch in China county (25º 31' N; 99º 16' W) with an elevation also of 200 m. The third site was located at the Experimental Station of Facultad de Ciencias Forestales, Universidad Autonoma de Nuevo Leon (24º 47' N; 99º 32' W; elevation of 350 m) located at Linares county. The main type of vegetation of the area is known as the Tamaulipan Thornscrub or Subtropical Thornscrub Woodlands (SPP-INEGI 1986). The native vegetation type covers much of northeastern Mexico and parts of southern Texas, USA. Spiny shrubs and small trees dominate this thornscrub, but grasses, forbs, and succulents are also prominent. In general, the three sites used in this study are grouped under a similar climatic pattern (subtropical and semiarid with warm summer) with an annual precipitation that ranges from 650 to 800 mm with a bimodal distribution (peaks rainfall are during May, June and

August, September). Monthly mean air temperature of the region ranges from 14.7^{o}C in January to 22.3^{o} C in August, although daily high temperatures of 45^{o}C are common during summer (González et al. 2004). In this study, seasonal rainfall and mean air temperatures that were recorded by land meteorological stations located in each site, they are shown in Table 4.1 Dominant soils are deep, dark-gray, lime-gray, lime-clay vertisols, with montmorillonite, which shrink and swell noticeably in response to changes in soil moisture content. Research sites were chosen since they are representative of the native vegetation and habitat of the white-tailed deer as well as, in this region the game purposes is a common leisure activity.

Shrub species such as *Castela erecta* T. & G. Rose (Rutaceae), *Celtis pallida* Torr. (Ulmaceae), *Forestiera angustifolia* Torr. (Oleaceae), *Lantana macropoda* Torr. (Verbenaceae) and *Zanthoxylum fagara* (L.) Sarg (Rutaceae) that are representative of the native vegetation of northeastern Mexico and the subtropical savanna ecosystems of southern Texas, USA (Everitt et al. 2002) and are consumed by range ruminants (Ramírez 2009; Domínguez et al. 2011) were used for micromineral analysis. In addition, these species show a wide range of adaptation to drought stress, are abundant and dominant in this type of vegetation (González et al. 2010).

Terminal shoots with fully expanded leaves from four different plants per species were randomly chosen (Cochran 1977) from a 50 m x 50 m representative and undisturbed thornscrub plot located in each site. Collections were undertaken, seasonally during two consecutive years: in summer, 2004 (August 28); fall, 2004 (November 28); winter, 2005 (February 28); spring, 2005 (May 28); summer, 2005 (August 28); fall, 2005 (November 28); winter, 2006 (February 28) and spring, 2006 (May 28). Shoots were excised and sampled (about 800 g) from the middle side of four plants (replications) of each species. Leaves were placed into paper bags and stored, and then samples were transferred to laboratory for mineral analyses.

Quadruplicate samples of each plant species were used for analyses. Partial dry matter (DM) was determined subjecting samples to oven at 55 °C during 72 h, then were ground in a Wiley mill (1 mm) and stored in plastic containers for further analyses. Mineral content was estimated by incinerating samples in a muffle oven at 550 °C, during 5 hours. Ashes were digested in a solution containing HCl and HNO_3, using the wet digestion technique (Cherney 2000). Concentrations of Cu, Fe, Mn, and Zn were determined by atomic absorption spectrophotometry (air/acetylene flame) using a Varian spectrophotometer (model SpectrAA-200; Varian Australia Pty Ltd., Mulgrave, Victoria, Australia) (AOAC 2000). Mineral data were statistically analyzed using one-way analysis of variance with a multi-factorial arrangement being years, sites and seasons the factors. When the F-test was significant ($P<0.05$), differences were validated using the Tukey´s honestly significant difference. Pearson correlation coefficients were performed between mineral content, and rainfall and temperature values registered during the two-year study. All applied statistical methods were computed using the SPSS package (Version 9).

4.4. RESULTS AND DISCUSSION

All plants had Cu, Fe, Mn and Zn contents that were significantly different among sites, years and seasons. The interactions site*year, site*season, year*season and site*year*season were also significant. In general, Linares site, where rainfall (Table 4.1) was higher, resulted with the highest trace element concentrations which coincides with the peak summer rainy season. Moreover, all plants during second year in summer season had the highest values. However, China site in first year and during winter and spring seasons had the lowest records.

As an approach to relate adverse environmental conditions to resource use efficiency in studied species, according to González et al. (2010), in general, it was found that *Castela texana*, *Celtis pallida* and *Forestiera angustifolia* showed higher and significantly xylem water potential values than *Lantana macropoda* and *Zanthoxylum fagara* under drought conditions, which allow them to provide under these critical conditions trace elements to ruminants.

4.4.1. Content of Cu

Copper content (Table 4.2) was higher in *Lantana macropoda* and lower in *Forestiera angustifolia*. Rainfall ($r = 0.71$; $P<0.001$) and temperature ($r = 0.69$; $P<0.001$) registered during the two-year study positively influenced Cu content in all plants. Apparently, most evaluated plants, only during summer and autumn in all sites, had Cu levels that could meet the metabolic requirements of an adult range white-tailed deer of 8 mg Cu kg^{-1} of diet dry matter (NRC 2007). Low Cu concentrations in dry seasons (winter and spring; Table 4.2) are also reported in shrubs and trees from semiarid regions (Barnes et al. 1990; Ramírez et al. 2001; Moya et al. 2002; Cerrillo et al. 2004; Ramírez and Núñez 2006; Ramírez et al. 2006) and in tropical native legumes (Norton and Poppi 1995).

Low Cu levels in plants might be caused by the high pH of the soils of these regions (Spears 1994) which are about from 7.5 to 8.5. High dietary fiber (Spears 1994; Ramírez et al. 2000; Guerrero et al. 2012) during dry seasons might have also reduced availability of

Cu. Copper deficiency can be the result of low levels of the mineral in the soil and in forages raised on the soil; this is the primary Cu deficiency. However, both the feed and the soil can have adequate copper levels but its absorption can be interfered by minerals known as Cu antagonists such as lead, Fe, Mn, various sulfates, Cd, and Mo. This is the secondary Cu deficiency (Whitehead 2000).

4.4.2. Content of Fe

Iron content (Table 4.3) was higher in *Lantana macropoda* and in *Zanthoxylum fagara* was lower. Temperature ($r = 0.59$; $P<0.001$) and rainfall ($r = 0.63$; $P<0.001$) registered during the two-year study positively influenced Fe content in all plants. Wet seasons (summer and autumn) were higher than dry seasons. All plants, in all seasons and in both years, contained Fe levels in substantial amounts to meet white-tailed deer requirements of 40 mg Fe kg^{-1} of diet dry matter (NRC 2007).

Similar findings were reported by Ramírez et al. (2001), Moya et al. (2002), Ramírez and Núñez (2006), Ramírez et al. (2010) and Guerrero et al. (2012) who evaluated the Fe content in browse species that grow in semiarid regions of Mexico. They sustained that Mexican browse species had Fe levels in large amounts to meet the Fe requirements of adult range small ruminants. Iron deficiency seldom occurs in browsing and grazing ruminants due to generally adequate pasture concentrations and contaminants of plants by soil. Soil contamination of forages and direct soil consumption often provide excess quantities of dietary Fe (McDowell 2003).

4.4.3. Content of Mn

Manganese content (Table 4.4) was higher in *Forestiera angustifolia* and in *Celtis pallida* was lower. Rainfall (r = 0.69; P<0.001) and temperature (r = 0.70; P<0.001) registered during the two-year study positively influenced Mn content in all plants. Dry seasons (winter and spring) were lower than wet seasons. With exception of *C. pallida* in dry seasons, most plants in all seasons had Mn concentrations to meet the metabolic requirements of adult range white-tailed deer (30 mg Mn kg^{-1} of diet dry matter; NRC 2007).

Low Mn levels, in dry seasons, of native shrubs and small trees growing in different rangelands of Mexico were also reported by Ramírez et al. (2001), Cerrillo et al. (2004), Ramírez and Núñez (2006), Ramírez et al. (2006), and Guerrero et al. (2012). Additionally, they found that high levels of Ca in Mexican browse species may increase Mn requirements, possible due to obstruction of Mn assimilation (McDowell 2003), and accessibility of Mn may be compromised when high quantity is located in the cell wall (Spears 1994).

4.4.4. Content of Zn

Zinc content (Table 4.5) was higher in *Lantana macropoda* and in *Zanthoxylum fagara* was lower. Peaks of Zn levels appeared to be related to summer and autumn rainfall (r = 0.65; P<0.001) and temperature (r = 0.70; P<0.001). It seems that only *Lantana macropoda* and *Forestiera angustifolia* had sufficient levels of Zn to meet the metabolic requirements of white-tailed deer of 30 mg Zn kg^{-1} of diet dry matter (NRC 2007).

Some shrubs that occur in Texas, USA and northeastern Mexico (Ramírez et al. 2001; Moya et al. 2002) had also Zn levels that varied seasonally, but only a few of them had levels of Zn to meet domestic and white-tailed deer requirements (Barnes et al. 1990). Conversely, Cerrillo et al. (2004), Ramírez and Núñez (2006) indicated a relevant potential mineral intake of Zn by range Spanish goats browsing in north and northwestern regions of Mexico, respectively.

4.5. CONCLUSIONS

Low rainfall and temperature, which occurred during winter and spring, affected mineral content in the evaluated plants. However, most plants had higher levels of the tested minerals during summer and autumn, when rainfall and temperature were high. It seems that Fe and Mn contents, in all plants and all seasons, can be sufficient for the metabolic requirements of an adult range white-tailed deer; however, Cu and Zn contents were marginally deficient in some plants in dry seasons.

The higher mineral content in all plants during the second year of the study may be explained by the fact that the Hurricane Emily occurred in the region registering more rainfall during the summer and autumn of 2005 than the previous year. In addition, higher mineral content in Linares site (undisturbed during the last 25 years) may be related to the higher historical precipitation (600-800 mm) compared to the other sites (400-600 mm). Thus, the positive relationships between mineral content and seasonal mean temperatures and rainfall, reflects the plasticity of how native trees and shrubs species deal with seasonal water deficits, extreme temperatures (frost or heat) and excessive irradiance levels as main multiple stresses that may co-occur either during the dry or wet seasons.

Although *Lantana macropoda* showed the highest content in trace elements, all species contribute somehow with the minimum nutritional requirements, except for Cu; therefore, plant diversity is essential to meet nutritional needs.

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Table 4.1. Seasonal means temperatures (°C) and accumulated rainfall (mm) registered in the three sites of the study.

Seasons	Sites-counties					
	Los Ramones		Linares		China	
	Temperature	Rainfall	Temperature	Rainfall	Temperature	Rainfall
First year						
Summer 2004	23.6	457	23.6	447	22.8	429
Autumn 2004	19.4	131	22.1	97	17.7	96
Winter 2005	11.3	31	13.4	35	10.1	28
Spring 2005	18.2	140	20.5	123	16.5	96
Total		759		702		649
Second Year						
Summer 2005	24.5	486	23.4	465	23.1	422
Autumn 2005	19.5	301	19.2	316	17.2	294
Winter 2006	11.5	14	9.7	9.0	8.7	24
Spring 2006	19.9	102	19.6	172	18.8	158
Total		903		962		898

Table 4.2. Seasonal means of Cu content (mg kg^{-1} dry matter) in native plants from northeastern Mexico.

Sites	Season and year	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
China	Summer 2004	11.1	10.2	9.9	16.5	11.9
	Autumn 2004	9.1	9.6	9.4	15.9	11.4
	Winter 2005	8.8	8.4	8.2	14.3	10.5
	Spring 2005	8.1	6.5	7.6	13.6	8.6
	Summer 2005	12.1	11.0	10.2	17.2	12.5
	Autumn 2005	10.6	9.8	9.3	16.4	11.2
	Winter 2006	9.4	8.5	8.0	15.3	10.8
	Spring 2006	9.2	6.9	6.5	14.2	9.7
Linares	Summer 2004	12.6	14.6	10.4	22.2	13.4
	Autumn 2004	10.5	11.2	9.5	19.6	12.6
	Winter 2005	9.6	10.0	8.3	17.5	11.4
	Spring 2005	8.1	8.8	6.8	16.4	10.3
	Summer 2005	13.1	16.2	10.9	24.2	14.5
	Autumn 2005	12.6	12.4	10.2	21.3	13.4
	Winter 2006	10.6	11.4	8.6	19.6	12.4
	Spring 2006	8.9	10.2	7.2	17.4	11.2
Los Ramones	Summer 2004	10.4	9.7	6.8	15.4	11.1
	Autumn 2004	8.2	8.2	6.2	14.6	10.2
	Winter 2005	8.4	7.6	5.4	13.5	9.7
	Spring 2005	7.5	6.3	6.5	12.4	9.4
	Summer 2005	11.6	10.8	7.3	16.2	12.5
	Autumn 2005	9.2	8.9	6.8	15.4	11.6
	Winter 2006	8.1	7.9	6.2	14.3	10.6
	Spring 2006	7.9	6.8	5.8	13.1	9.6
	Grand Mean	9.8	9.7	8.0	16.5	11.3
	SEM	0.6	1.1	0.4	0.5	0.5
	Effects	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	<0.001	<0.001	<0.001
	Sites (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001

SEM = standard error of the mean; n = 4; P = probability.

Table 4.3. Seasonal means of Fe content (mg kg^{-1} dry matter) in native plants from northeastern Mexico.

Sites	Season and year	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
China	Summer 2004	160	225	140	249	112
	Autumn 2004	146	186	128	181	95
	Winter 2005	119	152	106	162	87
	Spring 2005	105	95	102	155	75
	Summer 2005	186	259	191	271	123
	Autumn 2005	155	191	157	212	111
	Winter 2006	125	166	142	201	96
	Spring 2006	115	121	135	166	88
Linares	Summer 2004	165	314	232	372	266
	Autumn 2004	156	245	185	225	203
	Winter 2005	127	226	145	174	187
	Spring 2005	115	175	122	166	136
	Summer 2005	216	368	242	786	290
	Autumn 2005	186	250	195	663	248
	Winter 2006	156	238	156	178	198
	Spring 2006	123	186	132	151	192
Los Ramones	Summer 2004	151	202	135	178	108
	Autumn 2004	139	179	126	138	92
	Winter 2005	115	141	100	115	85
	Spring 2005	100	94	98	96	81
	Summer 2005	155	226	181	222	111
	Autumn 2005	146	224	147	175	96
	Winter 2006	117	181	133	126	87
	Spring 2006	102	98	98	110	83
	Grand Mean	141	198	147	228	135
	SEM	1.6	2	1.5	2.3	1.3
	Effects	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	<0.001	<0.001	<0.001
	Sites (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001

SEM = standard error of the mean; n = 4; P = probability.

Table 4.4. Seasonal means of Mn (mg kg^{-1} dry matter) in native plants from northeastern Mexico.

Sites	Season and year	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
China	Summer 2004	51.4	49.4	65.2	41.5	52.5
	Autumn 2004	50.2	36.2	50.4	40.4	41.4
	Winter 2005	48.6	24.6	47.6	38.6	39.9
	Spring 2005	44.5	24.2	44.5	37.1	38.7
	Summer 2005	53.6	53.3	40.1	43.6	45.1
	Autumn 2005	50.4	39.4	50.6	42.4	43.0
	Winter 2006	45.6	35.6	49.4	41.4	41.4
	Spring 2006	43.6	33.2	46.2	38.5	39.6
Linares	Summer 2004	61.3	56.4	50.4	47.7	53.8
	Autumn 2004	56.8	42.1	49.6	45.4	45.7
	Winter 2005	44.5	38.4	46.4	42.4	41.1
	Spring 2005	38.9	29.6	46.2	40.2	39.8
	Summer 2005	63.6	66.6	58.6	48.5	81.6
	Autumn 2005	58.5	46.2	55.6	45.8	74.7
	Winter 2006	49.5	42.1	53.4	44.5	66.7
	Spring 2006	40.6	34.6	52.4	42.7	56.7
Los Ramones	Summer 2004	50.2	48.6	48.6	40.2	48.7
	Autumn 2004	49.7	33.9	46.4	39.7	45.3
	Winter 2005	47.2	30.8	43.2	37.9	41.2
	Spring 2005	40.2	22.0	39.8	36.5	37.6
	Summer 2005	52.6	42.9	49.5	42.4	49.4
	Autumn 2005	50.2	37.7	48.6	40.2	44.3
	Winter 2006	49.2	31.2	45.4	39.5	40.5
	Spring 2006	42.1	27.7	40.3	37.2	38.6
	Grand Mean	49.4	38.6	49.7	41.4	48.2
	SEM	0.5	0.5	0.3	0.2	0.3
	Effects	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	<0.001	<0.001	<0.001
	Sites (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001

SEM = standard error of the mean; n = 4; P = probability.

Table 4.5. Seasonal means of Zn content (mg kg^{-1} dry matter) in native plants from northeastern Mexico.

Sites	Season and year	*C. erecta*	*C. pallida*	*F. angustifolia*	*L. macropoda*	*Z. fagara*
China	Summer 2004	23.6	19.6	39.7	33.7	20.1
	Autumn 2004	21.4	18.2	35.4	29.5	17.6
	Winter 2005	20.2	16.7	32.3	27.6	16.2
	Spring 2005	17.5	14.2	28.2	26.2	15.1
	Summer 2005	25.6	21.4	41.4	35.2	21.4
	Autumn 2005	23.5	19.3	37.2	34.3	19.6
	Winter 2006	21.4	18.6	35.3	30.5	18.4
	Spring 2006	18.6	16.2	29.2	28.6	16.2
Linares	Summer 2004	30.6	23.6	43.4	51.3	22.2
	Autumn 2004	27.5	21.4	41.1	48.1	21.2
	Winter 2005	25.4	18.2	38.2	45.4	20.3
	Spring 2005	22.3	16.5	33.5	43.2	18.6
	Summer 2005	32.6	33.5	54.2	67.3	24.2
	Autumn 2005	30.4	27.6	50.3	60.9	22.1
	Winter 2006	28.6	25.4	46.7	57.7	21.9
	Spring 2006	24.5	19.2	42.4	55.6	18.7
Los Ramones	Summer 2004	22.6	18.1	37.6	31.0	18.1
	Autumn 2004	20.2	17.9	33.5	29.6	16.2
	Winter 2005	18.6	15.7	30.2	27.2	14.7
	Spring 2005	16.5	13.1	26.5	25.4	12.5
	Summer 2005	24.8	20.1	39.6	33.5	18.9
	Autumn 2005	22.5	18.6	35.2	31.2	17.6
	Winter 2006	20.3	17.5	33.1	29.1	16.2
	Spring 2006	17.9	16.8	27.2	26.9	13.5
	Grand Mean	23.2	19.5	37.1	37.8	18.3
	SEM	0.4	0.3	0.5	0.6	0.4
	Effects	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	<0.001	<0.001	<0.001
	Sites (B)	<0.001	<0.001	<0.001	<0.001	<0.001
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001

SEM = standard error of the mean; n = 4; P = probability.

5. CHEMICAL COMPOSITION OF SHRUBS BROWSED BY WHITE-TAILED DEER (*Odocoileus virginianus* texanus)[3]

5.1. ABSTRACT

The Tamaulipan thornscrub ecosystem in northeastern Mexico, has a diversity of woody plants species which are used as forage to white-tailed deer. The objectives were to determine chemical composition of *Acacia amentacea, Castela erecta* Turp. *ssp. Texana, Celtis pallida, Croton cortesianus, Forestiera angustifolia, Karwinskia humboldtiana, Lantana macropoda, Leucophyllum frutescens, Prosopis laevigata, Syderoxylon celastrinum* and *Zanthoxylum fagara. S*easonally compared the results from three sites of study were used to know their nutritive value. The samples were collected on a seasonally basis from summer 2004 to spring 2006 in China, Linares and Los Ramones counties, in Nuevo Leon state, Mexico and evaluated for contents of Organic Matter (OM), Total Ashes (tA), Crude Protein (CP), Cellular wall (NDF), Acid Detergent Fiber (ADF), Lignin (L), Hemicellulose (H), and Cellulose (C), dry matter digestibility (DMD), digestible energy (DE), metabolizable energy (ME) and insoluble neutral detergent fiber (INDF). On a species basis, there were significant differences ($P<0.001$) in the triple interaction (year*site*season) for CP (16%), AFD (29%), NFD (46%), H (17%), L (14%) and C (15%), DMD (61 %), DE (2.9 Kcal Kg^{-1} DM), ME (2.4 Mcal Kg^{-1} DM), and INDF (27 g Kg^{-1} DM). The nutritional value was higher, for *C. pallida, Z. fagara* and *F. angustifolia*

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basis in their high content of protein, low content of cell wall, high DMD, ED and ME, especially during winter. However, this species are generally low in the energy content in order to meet white-tailed deer requirements, diversity of native species could complement specifically during winter season.

5.2. INTRODUCTION

Lands dominated by woody species, namely scrublands, savannas and forest ranges are a substantial portion of the world´s rangelands and they play an important role in areas with a long dry period and harsh environmental conditions. In these conditions, herbaceous forage is low quality and scarce to meet requirements of range ruminants. Shrubs have high nutritive value (protein, vitamins and minerals), low cost and diversity even some of them are preferred by range ruminants, consequently they are a potential option to be used in range ruminant productions system, especially in those extensive systems (Le Houerou, 2000; Ramírez- Lozano *et al*., 2000; Parissi *et al*., 2005; Ramírez, 2009; Azim *et al*., 2011; Kökten *et al*., 2012).

In some regions of Pakistan, during the dry and crop-fallow season, farmers traditionally feed indigenous fodder species to meet nutritive requirements of the grazing animals. Research from that area revealed that shrub foliage are a good source of nutrients (protein, fats, carbohydrates, fiber and minerals) and they should be used to cover deficit of nutrient substrata to the ruminants (Azim *et al*., 2011).

In Mexico, scrubland area is approximately 40% of total area covered by vegetation (García-Hernández and Jurado, 2008). This kind of vegetation is a source of energy, food and construction materials for human being; particularly, those arid and semiarid regions provides food with high nutritive value (nitrogen, energy, vitamins and minerals) to domestic and wild ruminants mainly in the long dry periods (Dante and Martínez, 1994; González-Rodríguez and Cantú-Silva, 2001; Ramírez-Lozano and González-Rodríguez, 2010).

The major kind of semiarid vegetation in northeast Mexico is the Tamaulipan thornscrub that is composed by shrubs and trees dense and thorny; they are distinguished by their wide rank of taxonomic groups showing different development patterns, foliar longevity, growing dynamics, and phenological development (Ramírez-Lozano and González-Rodríguez, 2010). It is localized at northeast of Mexico in the physiographic province called Coast Plain of The Gulf. It starts in Coahuila at the Sierra Madre Oriental basis, and then it continues to the East to reach the north half of Tamaulipas state. It consider the southwest Texas inside in the United States of America from sea level in gulf coast to near of 300 masl of north border of this eco region where some mountains protrude (Everitt *et al*., 2002).

The ecoregion has a wide range, they have been used traditionally as a livestock forage source and has provided habitat to wildlife as white-tailed deer (Ramírez, 2004). Diet and nutrition of the white-tailed deer is affected mainly by availability (quantity and accessibility) and quality (nutritive counting and digestibility) of plant. Additionally, the seasonal changes influence the plant abundance, their growing state and nutritive features (Richardson, 1999).

The white-tailed deer eats the scrubland vegetation, this make it a browser. Despite it prefers the herbage more that shrub, frequently they seems to be forced to consume shrubs if the preferred food are not in the rangeland or the nutritive quality is decreasing.

In the most studies of diet, browsing is higher than 50% in white-tailed deer annual diet. There are some causes to explain it skills to consume shrubs and little trees. As Fulbright and Ortega (2007) explain, white-tailed deer and shrubs have evolved together, the plants developed features that allow to survive despite to being consumed and otherwise, the white-tailed deer is adapted to morphological changes in plants like leaves size that may be consumed by the small snout of the deer, avoiding sharp spines or stems. This situation makes it capable to consume quickly, higher quantities of forage.

The white tailed deer always will try to keep his diet with high quality in order to satisfy his nutritional needs and at the same time adjusting the diet components while the forage plants change their quality. If one or both factors are limited, they will cause a detriment in the deer nutrition (Richardson, 1999). Browsing is not casual during the most of the year because the native shrubs from northeast Mexico have high protein content and other nutrients to satisfy cervid demand.

Has been documented that diet of the white-tailed deer is high in shrubs selected during the year; and it has reached near of 85%, even when the structure of the vegetation at northeast of Mexico registered 68%, this trend was higher in June and lower in April. It has been showed that *A. rigidula* composes 40% in the monthly diet of the white tailed deer in most ranches at northeast Mexico (Ramírez *et al*., 1997).

The forage availability is not generally a problem because have been identified 32 species of shrubs consumed by this cervid and they are indigenous of flora from some municipalities of Nuevo Leon, Mexico corresponding to Tamaulipan thornscrub in Coast Plain of the Gulf (Ramírez *et al*., 1997).

Availability is a key factor in the shrubs content in diet. If a particular category of plants like herbs are not available in the white tailed deer grazing area, this will be reflected in the higher preference for shrub, cacti and probably in native grasses. However, the exception is when scrubland has been eliminated and substituted by introduced grasses or naturalized grasses like *Cenchrus ciliaris* (Ramírez, 2004).

The ruminal microorganisms are capable of incorporate in their own amino acid proteins, like ten essential amino acids to the mammals. The microbial protein synthesis depends of different factors like the sources of carbohydrates and protein, the voluntary consume, the coordination of ruminal functions, the ruminal recycling of microorganisms and antinutritional factors from plants consumed. The microbial protein has a special role in ruminants feed with diets containing high fiber and low nitrogen; in that case, the microbial protein could be the unique protein source to ruminants (Rodríguez *et al*., 2007).

In Nuevo Leon state, in particular, a lot of trees and shrubs from legume species are utilized like food to livestock because they keep their green foliage and at the same time a relatively high content of nutrients all around year (Ramírez-Lozano and González-Rodríguez, 2010).

The nutritive value of forage is determined by its chemical composition and ease digestibility, but chemical composition is determinate by the nature of the plant (Buxton and Fales, 1994). The chemical condition suffers changes as the plant matures and may be further modified by the environmental conditions during growth like soil fertility, season, temperature, shade, water stress, etc. (Foroughbakhch *et al*., 2007).

The nutritive quality of forage is determined by its nutrient content and by the animal capacity to digest and use that food. Janick *et al*. (2008) comment that digestibility is limited by digestion degree of cell wall because a part of this is not available to microbial digestion inside rumen even if it keeps in during infinite period of time. This feature is affected by the maturity of the forage but also the environment modifies the impact of maturity in to the plant (Ramírez, 2009). As consequence of cellular elongation and differentiation (due subtle alterations of the chemical structure of cell wall components) the insoluble and indigestible compounds increase in the vegetal cells (Ramírez-Orduña *et al*., 2002). The temperature, water stress, solar radiation, nutrients deficiency and plagues are causes of stress in plants and in these cases the cell wall is the first defense line versus some of these factors causing stress. In the developing of a secondary wall, lignin is an important component of protection for the plant, although to animals consuming them, the lignification limits the nutrient availability from cell wall (Jančík *et al*., 2008; Ramírez, 2009). This study was conducted with the objectives of 1) determine the chemical composition of 11 native shrubs in the northeast Mexico and 2) to compare the results between four seasons of the year in a period of two years in three sampling sites. Objectives were developed from the hypothesis that browse plants, growing in northeastern Mexico are good nutritional quality to adult range white-tailed deer.

5.3. MATERIAL AND METHODS

The study was developed in the biotic province named Tamaulipan Thornscrub or Subtropical Thornscrub that is located at northeastern Mexico in the physiographical province known as the Coastal Gulf Plain. It begins in the eastern part of the Coahuila State, in Mexico at the base of the Sierra Madre Oriental, and then proceeds eastward to encompass the northern half of the state of Tamaulipas, and into the United States through the south western side of Texas along almost 362 km between coast and deciduous scrublands of the Sierra Madre Oriental, both sides of Rio Grande in Texas and northeast Mexico. Elevation increases northwesterly from sea level near the Gulf Coast to a base of about 300 m near the northern boundary of the ecoregion, from which a few hills or mountains protrude. The thorn shrubs and trees dominate the landscape but also there are grasses, herbaceous and succulents prominent. Combined, rangeland element grasses, like in savannah and moorland, legume shrubs and trees are included in this region. All together compose a third part of woody diversity, this particular combination is used by locals as grassland to intensive livestock, source of wood to construction and charcoal (Everitt *et al*., 2002).

5.3.1. Sampling

This study was carried out at three sampling sites situated in the state of Nuevo Leon. The first site was located at "Zaragoza" ranch in China county (25º 31' N; 99º 16' W). It has an elevation also of 200 m. The second site was located at the Campus of the Facultad de Ciencias Forestales, Universidad Autónoma de Nuevo Leon, located at Linares county (24º 47' N; 99º 32' W); it has an elevation of 350 m. The third site was located at "El Abuelo" ranch in Los Ramones county (25º 40' N; 99º 27' W) with an elevation of 200 m.

Vegetation at the three sites is composed by browse plants that are consumed by range livestock (cattle, sheep and goats) and wildlife (white-tailed deer), and is representative of the central region of the state of Nuevo Leon.

In general, the three sites chosen in this study are grouped under a similar climatic pattern (subtropical and semiarid with warm summer) with an annual precipitation that ranges from 650 to 800 mm with a bimodal distribution (peaks rainfall are observed in May, June, August, and September). Monthly mean air temperature of the region ranges from 14.7^{o} C in January to 22.3^{o} C in August, although daily high temperatures of 45^{o} C are common during summer (González *et al*., 2004). Los Ramones and China sites have not registered livestock activities in the last five years, and Linares since the last 25 years. The main type of vegetation of the area is known as the Tamaulipan Thornscrub or Subtropical Thornscrub Woodlands. Dominant soils are deep, dark-gray, lime-gray, lime-clay vertisols, with montmorillonite, which shrink and swell noticeably in response to changes in soil moisture content (INEGI, 2002).

Studied species were: *Acacia amentacea* DC. (Fabaceae), *Castela erecta* Turp. *ssp. Texana* Torr. & A. Gray Cronquist (Simaroubaceae), *Celtis pallida* Torr (Ulmaceae), *Croton cortesianus* Kunth (Euphorbiaceae), *Forestiera angustifolia* Torr (Oleaceae), *Karwinskia humboldtiana* Roem. Et Schult (Zucc. (Rhamnaceae), *Lantana macropoda* Torr. (Verbenaceae), *Leucophyllum frutescens* (Berl.) I.M. Jhonst. (Scrophulariaceae), *Prosopis laevigata* (Humb. & Bonpl. Ex Willd.) M.C. Jhonston. (Fabaceae), *Syderoxylon celastrinum* (Kunth) (Sapotaceae) and *Zanthoxylum fagara* (L.) Sarg. (Rutaceae). These species are representative of the native vegetation of the northeastern Mexico and the subtropical savanna ecosystems of southern Texas, USA (Everitt *et al*., 2002) and are consumed by range ruminates and white-tailed deer (Quintanilla, 1989; Moreno, 1991; Valdés, 1995; Molina, 1994; Olguín, 2005; Ramírez, 2004, 2009; Ramírez *et al*., 2010a,b). At browsing height, terminal shoots with fully expanded leaves were randomly chosen from a 50 m x 50 m representative and undisturbed plot located in each site. Collections were undertaken, seasonally during two consecutive years: summer, 2004 (August 28); fall, 2004 (December 1); winter, 2005 (March 1); spring, 2005 (May 28); summer, 2005 (September 1); fall, 2005 (November 28); winter, 2006 (February 27) and spring, 2006 (May 28). Shoots were excised and sampled (about 800 g) from the middle side of three plants of each species. Leaves were placed into paper bags and stored. Thereafter, samples were transferred to the laboratory for analyses.

5.3.2. Chemical analyses

Partial dry matter (DM) was established by drying samples in an oven at 55 °C during 72 h, then grounded in a Wiley mill (1 mm) and stored in plastic containers for further analyses. By triplicate, samples were analyzed for Organic Matter (OM) and Ashes (A) according AOAC (1995); Crude Protein (CP) by micro Kjeldahl and ash content (AOAC, 1997). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (L) were performed according to the procedures described by Van Soest *et al*. (1991). Hemicellulose (NDF–ADF) and cellulose (ADF–L) were estimated by difference. Although the value of accurate digestibility data is unbiased, obtaining actual data is time consuming, expensive, and requires large amounts of the forage samples that was not feasible in this study then dry matter digestibility (DMD, %) was estimated using the formula developed by Oddy *et al*. (1983): DMD = 83.58 - (0.824 x ADF%) + (2.626 x nitrogen %). Dry matter digestibility values were used to estimate digestible energy (DE, Kcal Kg^{-1} DM) using the regression equation reported by Fonnesbeck *et al*. (1984): DE = 0.27 + (0.0428 x DMD %). Then DE values were converted to Metabolizable Energy (ME, Mcal Kg^{-1} DM) using the equation proposed by Khalil *et al*. (1986): ME = 0.821 x DE (Kcal Kg^{-1}). Predictive equations derived in this study could be used in estimating nutrient digestibility and energy if relevant chemical composition is known without doing expensive feeding trials (Appiah *et al*., 2012). The insoluble neutral detergent fiber (INDF, g Kg^{-1} DM) was calculated from the equation developed by Jančík *et al*. (2008): INDF = –86.98 + (1.542 x NDF %) + (31.63 x L %).

5.3.3. Statistical analyses

Using a completely random design with factorial arrangement, the factors were years (A, 2), sampling sites (B, 3) and seasons (C, 4) and with three repetitions all the statistical analyses were carried out using SPSS computer software for Windows Version 13. Media differences were calculated using Tukey test (P<0.001).

5.4. RESULTS AND DISCUSSION

5.4.1. Content of Organic Matter, Ashes and Crude Protein

Organic Matter (OM) and Ash content (A) and Crude Protein (CP) were significantly different between years, sites and seasons (P<0.001), except by the first case (Table 5.1) in some species (*A. amentacea*, *C. erecta*, *F. angustifolia*, *S. celastrinum* and *Z. fagara*) and ashes (*A. amentacea*, *C. pallida*, *F. angustifolia*, *L. frutescens*, *P. laevigata* and *Z. fagara*) and in *F. angustifolia* for the third.

The highest and lowest value of OM content was present in Los Ramones site, the first one of 94% in *F. angustifolia* during spring 2006 and the second one of 34% in *L. frutescens* during winter 2006 and in this case with the same value *P. laevigata* in summer 2004 in China. However, Linares and Los Ramones showed all species with most of the organic matter mainly in summer 05, probably associated with higher rainfall event (Emily Hurricane). Ash content was higher in *P. laevigata* (30%) in Linares site during summer 2004 and 1% in *F. angustifolia, S. celastrinum* and *L. frutescens*, in China (autumn 2005) and Los Ramones (summer 2004) as is observed in Table 5.2 According Kökten *et al*. (2012), the organic matter has a negative correlation with ash content, coincidence in *F. angustifolia* to this study; all species together presented higher content of ashes than organic matter in winter.

The highest concentration of CP (Table 5.3) was higher in *P. laevigata* (winter 2005; 33%; China), while the lower was present in *L. frutescens* (summer 2004; 10%; Linares) and *C. erecta* (autumn 2004; spring 2005; China and Linares). During the second year, crude protein was higher than during the first one, particularly during spring of 2006. Parlak *et al*. (2011) studied woody species and they found that during spring the content of crude protein increases. According these authors protein synthesis is stimulated as the plants starts to grow in the spring, the number of young cells increase and the physiological events are induced. To present results, the highest content of crude protein coincides with the highest record of precipitation just last summer rainfall, assuming foliar growing. The group of the studied species offers 16% of crude protein during critic periods of winter in the sampling sites while *F. angustifolia* and *P. laevigata* show higher content, especially during winter and spring. Particularly these species have been evaluated before by Morales-

Rodríguez *et al*. (2003) and Domínguez-Gómez *et al*. (2011) founded this species and other native shrubs may be considered as good proteic complements for range ruminants, especially during winter due their effective degradability (69.3% *F. angustifolia*) and their content of PC (17-14%); furthermore, the samples taken for the winter season were made during late February and early March that could have influenced this regard as some species had already begun the process of leaf regeneration for this.

Organic matter, ashes and crude protein were similar to those reported by Ramírez-Lozano *et al*. (2000) in Marín municipality. Ashes and crude protein are similar to the results of Domínguez-Gómez *et al*. (2011) concerning to *A. amentacea*, *C. pallida* and *F. angustifolia*; moreover, about organic matter, Foroughbakhch *et al*. (2007) reported higher values in *S. celastrinum* (90.4%) and *C. erecta* (90.7%) but similar results to *A. amentacea* (18.4%), *C. pallida* (17.5%) and *Z. fagara* (18.6%). These authors confirmed that shrubs and trees had more crude protein after be compared with grasses during drought season.

In a study from north of Mexico developed by Guerrero (2009), the nutritive value was compared between herbs, shrubs and cacti recorded in ruminant diet in Durango, Mexico where *C. pallida* had the higher crude protein content (14.8%) in common with the present study. Likewise, Guerrero *et al*. (2012) analyzed plant species of north Mexico and found that they could be considered as desirable supplement, especially if the animals are feed with low quality diets, the protein content was calculated in 100 g kg^{-1} of DM (10% PC).

The crude protein content in ten of the eleven studied species is over the 7% of crude protein; according to Yousef and Rouzbehan (2008) microbial activity in rumen will be in danger if the diet has a lower content of crude protein. The crude protein content in the studied species meet the white-tailed deer requirements (NRC, 2007) similar to Ramírez (2004, 2009) and Domínguez-Gómez *et al*. (2011).

5.4.2. Content of cell wall

Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Lignin (L) content was significant different between years, sites and seasons. Double and triple interactions were also significantly different ($P<0.001$). In Table 5.4, cell wall (NDF) was higher in *Z. fagara* (72%) during summer 2005 in China. Contrary *L. macropoda* in autumn 2005 in Linares was the lowest (30%). The present study reports higher values than those reported for some species in common with Ramírez-Lozano *et al*. (2000), Ramírez-Orduña *et al*. (2002) and Guerrero (2009) at north of Mexico. According to Minson (1990) those forage plants with low cell wall content are soluble, rich in non-structural carbohydrates (starchy stocked in seeds and leaves). Gómez-Castro *et al*. (2006) determined that more that 40% of cell wall is associated with less food consume in ruminants; this might indicate low quality forage. The present study presented a declined in cell wall content after rainiest season (summer 2005). Similar tendency was present in Ramírez (2003) because in the same region after summer (rainy season) the cell wall content was the lowest. Sosa-Rubio *et al*. (2004) analyzed vegetative material of trees (in a different ecosystem) and determined a cell wall from 20 to 35% with high levels of digestibility. Mandujano *et al*. (2004) worked with deer activity in two kinds of rainforest in Jalisco Mexico, one of them evergreen associated to water bodies and the other deciduous. They studied preferences for deer habitat and forage quality. Their results indicated that deer prefer deciduous all the year, presumably due to lower risk to predators and availability of fruits rich in water and energy. Their results pointed out that forage present in deciduous forest had higher fiber content and low protein content in deer diet during dry season, at similar way to the present work. May be that digestible deer skills could play a role more important in this kind of investigations.

ADF content was higher in *A. amentacea* during winter 2005 (51%) and lower during autumn 2004 (13%) both in Los Ramones (Table 5.5). The ADF content was higher than those results reported by Foroughbakhch *et al*. (2007) and Domínguez-Gómez *et al.* (2011) and according to Gómez-Castro *et al*. (2006), a high ADF content is associated to low digestibility in ruminal level, while a high NDF is associated with low consume of forage. In this sense, this work coincides with *A. amentacea*.

López-Pérez *et al*. (2012) studied a simulated diet of white-tailed deer in Morelos, Mexico, and they showed that diet of deer was low in crude protein and ADF during winter (10.8 and 23 %) compared with autumn (15 and 31 %) and spring (14.2 and 26.2 %) and similar tendency is in the present work, specifically in crude protein deficiency during winter and adequate content of CP.

A study of comparison between shrubs and grasses preferred by cows was developed by Rossi *et al*. (2008) and they found that higher percentages of ADF directly affect degradability of forages at ruminal level (high content of structural components low digestible) and they assumed that browsing during dry season will be better because at increasing consumption of shrubs provide lower content of fiber than grasses.

As is showed in Table 5.6, the lignin content was higher in *A. amentacea* (34%) during winter 2005 in Los Ramones while the lowest content was 4% in *L. macropoda* during autumn 2005 in Linares. The highest percentages were present in Linares and Los Ramones during autumn and winter. The amount of lignin is positively associated with the maturity of plants and the latter characteristic is negatively related with rainfall (Hatfield *et al*., 1993).When forages from trees and shrubs have been studied, their high lignin content is associated with low digestibility of dry matter *in vitro* and has been demonstrated that this situation causes a negative effect in cell wall digestibility and consequently it turns in a reduced consume of forage, according to Foroughbakhch *et al*. (2007). If lignin content in plants is increased, then digestibility of organic matter significantly decrease, Moya *et al*. (2002) confirmed the negative influence of lignin on nutrient digestibility in shrub plants, but Rogosic *et al*. (2006) found that this does not influence the digestibility of crude protein and other cell wall compounds, particularly in *C. texana*, *B. celastrina* and *A. amentacea*, this could be similar to the present work. The *A. amentacea,* is similar to Domínguez-Gómez *et al*. (2011) results.

Soil fertility, temperature and light can affect directly or indirectly lignification according Ramírez (2009). To this respect Cash and Fulbright (2005) developed an experiment to know chemical composition and digestibility of two species of shrub seedlings at south of Texas. This experiment was conducted under greenhouse conditions and fertilization and without them. Their results revealed that under fertilization conditions both species had highest content of crude protein content but also higher lignin content.

Considering their crude protein content two species *A. amentacea* and *P. laevigata* could be a convenient crude protein source to white-tailed deer, however there is a negative correlation between NFD and ADF as well as dry matter consume and its digestibility, according to Kökten *et al*. (2012), these correlations will affect the general quality of *A. amentacea* and *P. laevigata* during drought period (low dry matter consume and low digestibility). Above facts allow us to deduce that nutritionally *C. pallida* is the best species. However, *C. pallida* is not a preferred species to white-tailed deer (Richardson 1999); he says that *C. pallida* is an emergent species when the favorites are scarce. Likewise, Rossi *et al*. (2008) found *C. pallida* as species with better nutritional quality in general terms according it high crude protein, low percentages of NDF and ADF, high digestibility values and low total polifenols.

Cellulose and hemicelluloses were significantly different between sites, plants and seasons. Double and triple interactions were also significantly different ($P<0.001$). The highest content of hemicellulose was registered in *Z. fagara* (55%) during summer 2005 in China and 0% was registered for *L. macropoda* during autumn 2005 in Linares (Table 5.7). According to Foroughbakhch *et al*. (2007) the high content of hemicellulose could be considered as potential source of energy to microorganisms of rumen therefore the studied species could offer low energy in autumn during the second year in the three sites.

The highest cellulose content (26%) was present in *L. macropoda* (summer 2004, autumn 2004 and autumn 2005). In Linares were present the highest values of cellulose in all species, while the lowest was of 6% in *F. angustifolia* during spring 2006, in china (Table 5.8). The general average was 17% in hemicellulose was higher than 15% of cellulose and this fact indicate that there are higher availability of energy through sugars and soluble carbohydrates.

Autumn, winter and spring have low average of cellulose in all species; this could not be a nutritive advantage to white-tailed deer under energetic perspective. Results of this investigation are similar with Ramírez *et al*. (2000) in particular for *A. rigidula* (*A.*

amentacea) and *C. pallida*; with Ramírez-Orduña *et al*. (2002) for *C. pallida.* The present results are similar to those of Guerrero (2009), particularly for the group of shrubs from north Mexico regarding the content of cellulose (18%). Considered that the chemical composition can affect the effective degradability in a negative form and in terms of metabolizable energy was positive. As higher fiber fractions will be lower dry matter digestibility and as cellulose and hemicelluloses are higher, then will be a good proportion of energy.

In this regard, Ramírez *et al*. (1997) mentioned that diversity is particularly important if the species have different developing stages during seasons of the year. Diversity of phenologies of plants increases the probability of availability, all year round of high quality forage. Likewise, according to Ramírez (2004), pods of mesquite (*Prosopis glandulosa*) are produced in winter and early summer as an important energetic source to white-tailed deer in the region. This fact allows deer to recover energy used during reproductive season. On the other hand, cactus forage (*Opuntia englemannii*) has a high digestibility of organic matter (energy) but is low in crude protein, phosphorous and sodium. The above described confirms the importance of species diversity in forages to meet nutritional requirements of white-tailed deer (Ramírez, 2004).

5.4.3. Digestibility and Energy

The dry matter digestibility (DMD) was significantly different among plant species (Table 5.9). *C. pallida* had higher ranges (from 59 to 81 %) followed by *Z. fagara* (63-79 %), the first one got the higher digestibility percentage in Los Ramones site during winter 2004 (81 %). The lower dry matter digestibility was recorded in *L. frutescens* (36-50 %). In

China the studied species reached 71-76 % as media values of digestibility during the first and second year, respectively but it was followed by Los Ramones (70-71 %) and Linares (67-71 %). By year the results revealed that except *A. amentacea* and *L. frutescens* in all studied sites had DMD values above 50 %. The DMD is one of the main factors determining the nutritive value of forage (McDonald *et al*., 1995); they believed that the basic determinant of forage digestibility is the plant anatomy. In this study, due to the positive relationship between DMD and DE (r = 0.93; P<0.001) and ME (r = 0.93; P<0.001), higher DMD implies higher DE and ME content. In recent studies about dry matter digestibility (DMD) have been proposed that this parameter is similar to digestible energy (DE) and it can be a good indicator of DE (Ramírez, 2004).

Digestible energy was significantly different among plant species (Table 5.10). *Z. fagara* (3.0-3.7 Kcal Kg^{-1} DM) had higher ranges followed by *C. pallida* to 3.7 Kcal Kg^{-1} DM) the second one showed the highest values during winter and spring of the first year (3.7 Kcal Kg^{-1} DM). This parameter was higher in Los Ramones during the first year and during the second one was higher in the three sites. As it is shown in Table 5.11, ME values were 2.3-3.1 Mcal Kg^{-1} DM in *C. pallida* and in *Z. fagara* from Mcal Kg^{-1} DM the highest values of Metabolizable energy. China site registered the highest values in Metabolizable energy. DMD and ME of the grazable plant material are related inversely with cell wall components and linearly with CP and ash, then, browse had low DMD and ME both generally associated with thick cell walls highly lignified NDF, and low level of protein (Parlak *et al*., 2011). Evaluated species of native shrubs had not ME values to satisfy the energy requirements for maintenance of white-tailed deer in general (4.6-5.8 Mcal per day; NRC, 2007), however, it meet prebreeding, breeding and early pregnancy of single fetus

(2.1-2.5 Mcal per day; NRC, 2007) but investigation in this area is required. The indigestible neutral detergent fiber (INDF) significantly varied among years, sites and seasons within eleven studied species (Table 5.12). *C. pallida* had the highest ranges (13-50 g Kg^{-1} DM) followed by *Z. fagara* (8-50 g Kg^{-1} DM) the first one had the highest value (50 g Kg^{-1} DM) in Linares during summer 2004. INDF content in the eleven species influenced negatively (r = 0.88; P<0.001) the DMD of all plants. Jančík *et al*. (2008) and Ramírez *et al*. (2009) founded that INDF increases in grasses as they mature, but in shrubs these may be related just with the time because the second year shows the highest values but do not dramatically.

There are evidences about white-tailed deer adaptability because they are capable to modify their nutritive requirements according to the habitat were it inhabits: white-tailed deer in southeast of Texas, in comparison with those of north may be an example of decreasing metabolizable energy compared with their relatives from north. This characteristic suggests an adaptation to semiarid environment (Strickland *et al*., 2005).

The results give a profile about nutritive value of eleven shrubs of northeast México but there are evidences about white-tailed deer adaptability because they are capable to modify their nutritive requirements according to the habitat were it inhabit. White-tailed deer in southeast of Texas, in comparison with those of north may be an example of decreasing metabolizable energy compared with their relatives from north. This characteristic suggests an adaptation to semiarid environment (Strickland *et al*., 2005). In Japan they have problems of barking pine plantations caused by deer, and they attribute that phenomenon to higher nutrient concentration in those barks with respect to the scarce surrounding vegetation (Jiang *et al*., 2005).

5.5. CONCLUSIONS

The chemical composition of eleven shrub species browsed by white-tailed deer brings, marginally, the crude protein for maintenance and metabolizable energy may be low to game purposes. It is marginal because there are variations in some seasons turning critical for example in winter, assuming white-tailed deer keep their nutritional requirements uniformly all year. Those species with highest crude protein content also contain high cell wall or fiber affecting forage degradability and therefore digestibility in rumen. Cell wall content may represent a limit to take advantage of nutritional qualities of shrub studied, independently of secondary compounds none analyzed. *C. pallida* and *F. angustifolia* resulted with the higher content of crude protein and energy and even there is a need to supplement white-tailed deer, diversity is a key factor in nutrient contribution of shrubs consumed because these shrub species have different developing cycle thorough year, even during drought period allow access to energy and crude protein. Both diversity and chemical composition show a great potential of native forages as food to white-tailed deer in northeast region in Mexico and consequently to a good management of deer and native shrubs.

5.6. REFERENCES

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Table 5.1. Seasonal means of organic matter (%) in native shrubs from northeastern Mexico.

Site	Season and year	*A. ame*	*C. ere*	*C. pal*	*C. cor*	*F. ang*	*K. hum*	*L. fru*	*L. mac*	*S. cel*	*P. lae*	*Z. fag*
China	Summer 2004	57	88	79	59	92	52	60	86	57	34	90
	Autumn 2004	41	89	73	40	91	49	55	83	52	46	90
	Winter 2005	39	91	75	70	na	47	69	86	51	74	81
	Spring 2005	44	92	83	57	na	54	59	85	47	51	86
	Summer 2005	50	85	75	66	88	62	70	87	54	68	90
	Autumn 2005	40	88	78	51	86	45	59	88	52	46	91
	Winter 2006	38	90	83	41	91	43	45	87	49	65	90
	Spring 2006	54	88	82	68	93	65	65	87	50	48	90
Linares	Summer 2004	48	85	74	73	na	59	69	85	54	50	92
	Autumn 2004	58	84	76	58	na	51	56	86	53	na	87
	Winter 2005	69	84	79	74	81	49	63	86	51	na	83
	Spring 2005	45	90	79	68	71	54	64	84	54	50	91
	Summer 2005	51	90	70	70	89	51	83	88	53	53	92
	Autumn 2005	42	80	65	64	89	57	69	80	54	51	88
	Winter 2006	37	88	72	49	82	45	54	83	47	48	86
	Spring 2006	44	91	79	55	88	42	52	87	48	47	89
Los Ramones	Summer 2004	42	90	80	66	89	54	73	65	57	52	88
	Autumn 2004	42	91	72	60	85	41	61	83	49	42	78
	Winter 2005	52	88	87	72	88	44	63	85	49	49	83
	Spring 2005	48	86	77	67	91	48	63	87	54	56	87
	Summer 2005	42	84	75	48	84	49	60	83	53	50	90
	Autumn 2005	40	81	76	51	91	49	52	81	55	49	91
	Winter 2006	36	88	79	57	84	37	34	84	50	69	90
	Spring 2006	58	93	85	64	94	62	61	66	50	51	90
	Grand Mean	47	88	77	60	87	50	61	83	52	52	88
	SEM	1.1	0.6	0.7	1.2	0.8	0.9	1.2	0.8	0.4	1.2	0.5
	Effects	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
	Year (A)	0.004	0.325	0.133	<0.001	0.200	<0.001	<0.001	0.906	0.124	0.009	<0.001
	Sites (B)	0.049	0.219	0.00	<0.001	0.000	<0.001	<0.001	<0.001	0.642	0.086	0.294
	Seasons (C)	0.060	0.017	0.000	<0.001	0.414	<0.001	<0.001	0.266	<0.001	<0.001	<0.001
	A x B	0.004	0.196	0.003	<0.001	0.001	<0.001	<0.001	0.325	0.312	0.329	0.005
	A x C	<0.001	0.078	0.034	<0.001	0.002	<0.001	<0.001	0.001	0.035	0.001	0.009
	B x C	<0.001	0.458	0.377	<0.001	0.006	<0.001	<0.001	<0.001	0.219	<0.001	0.043
	A x B x C	0.015	0.063	0.001	<0.001	0.050	<0.001	<0.001	<0.001	0.024	<0.001	0.040

na= not available; SEM= standard error of the mean; n = 10; P = probability. A. ame= *Acacia amentacea*; C. ere= *Castela erecta*; C. pal= *Celtis pallida*; C. cor= *Croton cortesianus*; F. ang= *Forestiera angustifolia*; K. hum= *Karwinskia humboldtiana*; L. fru= *Leucophyllum frutescens*; L. mac= *Lantana macropoda*; S. cel= *Sideroxylon celastrinum*; P. lae= *Prosopis laevigata*; Z. fag= *Zanthoxylum fagara*.

Table 5.2. Seasonal means of total ashes (%) in native shrubs from northeastern Mexico.

Site	Season and year	*A. ame*	*C. ere*	*C. pal*	*C. cor*	*F. ang*	*K. hum*	*L. fru*	*L. mac*	*S. cel*	*P. lae*	*Z. fag*
China	Summer 2004	4	6	10	5	11	6	2	8	4	5	6
	Autumn 2004	8	13	16	7	5	15	4	16	7	7	8
	Winter 2005	11	11	7	3	2	6	4	6	9	3	7
	Spring 2005	6	10	15	6	7	10	4	10	5	5	6
	Summer 2005	12	21	14	21	13	16	11	11	11	9	12
	Autumn 2005	7	3	8	5	1	4	5	6	1	5	7
	Winter 2006	10	4	17	6	5	15	12	21	5	2	14
	Spring 2006	3	11	7	6	4	4	5	8	8	4	3
Linares	Summer 2004	3	9	11	6	4	8	4	6	5	30	8
	Autumn 2004	7	11	20	12	8	10	6	12	4	6	10
	Winter 2005	12	11	6	4	3	11	4	7	6	3	10
	Spring 2005	5	7	11	7	5	7	5	16	8	6	12
	Summer 2005	8	9	14	7	5	8	4	8	7	5	7
	Autumn 2005	11	10	18	9	7	14	5	12	6	7	8
	Winter 2006	8	11	16	11	6	10	63	15	5	3	10
	Spring 2006	7	13	10	5	14	4	4	8	5	9	10
Los Ramones	Summer 2004	8	9	15	4	5	5	1	4	6	7	4
	Autumn 2004	6	9	20	9	6	9	4	18	8	9	8
	Winter 2005	2	11	4	3	2	8	2	4	5	2	8
	Spring 2005	10	9	13	5	5	9	3	7	5	6	10
	Summer 2005	6	6	14	6	3	9	2	5	12	10	6
	Autumn 2005	11	16	22	6	9	9	3	10	6	6	9
	Winter 2006	11	9	19	10	6	12	5	11	7	8	9
	Spring 2006	8	8	16	8	9	16	7	18	8	6	11
	Grand Mean	8	10	13	7	6	9	7	10	6	7	8
	SEM	0.6	0.8	1.0	0.8	0.7	0.8	2.5	1.0	0.5	1.1	0.5
	Effects	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
	Year (A)	0.043	0.618	0.015	<0.001	0.125	0.002	0.158	0.006	0.105	0.305	0.370
	Sites (B)	0.915	0.797	0.009	0.090	0.758	0.416	0.330	0.212	0.012	0.133	0.281
	Seasons (C)	0.091	0.884	<0.001	0.004	0.047	0.006	0.291	<0.001	0.004	0.004	0.162
	A x B	0.576	0.704	0.138	0.022	0.198	0.002	0.520	0.095	0.024	0.138	0.200
	A x C	0.156	0.020	0.000	<0.001	0.259	<0.001	0.243	<0.001	<0.001	0.197	0.185
	B x C	0.040	0.005	0.095	<0.001	0.003	<0.001	0.462	<0.001	0.053	0.234	0.025
	A x B x C	0.002	<0.001	0.283	<0.001	0.301	<0.001	0.423	<0.001	<0.001	0.005	0.630

na= not available; SEM= standard error of the mean; n = 10; P = probability. A. ame= *Acacia amentacea*; C. ere= *Castela erecta*; C. pal= *Celtis pallida*; C. cor= *Croton cortesianus*; F. ang= *Forestiera angustifolia*; K. hum= *Karwinskia humboldtiana*; L. fru= *Leucophyllum frutescens*; L. mac= *Lantana macropoda*; S. cel= *Sideroxylon celastrinum*; P. lae= *Prosopis laevigata*; Z. fag= *Zanthoxylum fagara*.

Table 5.3. Seasonal means of crude protein (%) in native shrubs from northeastern Mexico.

Site	Season and year	*A. ame*	*C. ere*	*C. pal*	*C. cor*	*F. ang*	*K. hum*	*L. fru*	*L. mac*	*S. cel*	*P. lae*	*Z. fag*
China	Summer 2004	15	12	21	24	11	17	11	18	12	19	14
	Autumn 2004	17	10	22	16	13	18	13	17	14	25	17
	Winter 2005	15	13	20	21	na	15	16	19	13	33	15
	Spring 2005	16	14	23	18	na	18	13	17	14	19	17
	Summer 2005	17	14	24	15	17	16	13	13	15	19	18
	Autumn 2005	16	14	20	18	13	17	11	14	15	17	20
	Winter 2006	14	12	19	16	11	15	14	14	15	24	12
	Spring 2006	16	13	25	19	14	18	14	19	12	21	25
Linares	Summer 2004	16	11	18	16	na	14	10	14	13	18	15
	Autumn 2004	18	12	21	17	na	17	14	17	13	na	14
	Winter 2005	21	13	24	17	15	16	12	20	14	na	13
	Spring 2005	16	10	20	20	11	18	11	16	14	21	16
	Summer 2005	16	15	21	17	16	18	13	18	18	21	19
	Autumn 2005	16	15	19	19	14	15	15	14	17	19	18
	Winter 2006	13	15	22	16	12	17	14	16	14	17	13
	Spring 2006	16	13	26	19	13	18	15	18	16	22	16
Los Ramones	Summer 2004	14	14	22	16	13	15	11	15	12	20	14
	Autumn 2004	13	14	17	17	12	15	11	14	13	21	15
	Winter 2005	18	12	30	19	12	17	16	17	14	20	16
	Spring 2005	15	11	20	19	13	18	18	19	14	18	16
	Summer 2005	19	14	24	17	14	17	14	17	12	20	16
	Autumn 2005	15	13	21	14	11	14	11	16	18	19	16
	Winter 2006	16	12	17	15	12	12	12	19	13	29	14
	Spring 2006	16	16	24	19	15	18	15	18	16	22	22
	Grand Mean	16	13	22	18	13	16	13	17	14	21	16
	SEM	0.2	0.2	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.5	0.4
	Effects	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
	Year (A)	0.006	<0.001	0.322	<0.001	0.013	0.009	0.001	<0.001	<0.001	0.989	<0.001
	Sites (B)	<0.001	0.047	0.139	<0.001	0.042	<0.001	0.024	0.013	<0.001	<0.001	<0.001
	Seasons (C)	0.198	0.547	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	0.009	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

na= not available; SEM= standard error of the mean; n = 10; P = probability. A. ame= *Acacia amentacea*; C. ere= *Castela erecta*; C. pal= *Celtis pallida*; C. cor= *Croton cortesianus*; F. ang= *Forestiera angustifolia*; K. hum= *Karwinskia humboldtiana*; L. fru= *Leucophyllum frutescens*; L. mac= *Lantana macropoda*; S. cel= *Sideroxylon celastrinum*; P. lae= *Prosopis laevigata*; Z. fag= *Zanthoxylum fagara*.

Table 5.4. Seasonal means of cell wall (FDN %) in native shrubs from northeastern Mexico.

Site	Season and year	*A. ame*	*C. ere*	*C. pal*	*C. cor*	*F. ang*	*K. hum*	*L. fru*	*L. mac*	*S. cel*	*P. lae*	*Z. fag*
China	Summer 2004	56	38	34	48	40	50	58	46	49	47	30
	Autumn 2004	61	36	38	42	40	67	48	45	42	57	53
	Winter 2005	58	41	38	57	na	60	59	55	39	33	40
	Spring 2005	55	45	42	48	na	41	49	52	44	50	56
	Summer 2005	51	45	35	51	43	46	47	38	46	47	72
	Autumn 2005	53	42	37	46	38	46	44	47	42	50	37
	Winter 2006	47	47	37	52	51	38	51	50	37	43	34
	Spring 2006	51	40	36	47	36	39	44	46	40	44	51
Linares	Summer 2004	61	47	32	50	na	48	49	61	43	59	46
	Autumn 2004	62	47	45	48	na	66	42	61	43	na	45
	Winter 2005	63	48	58	53	45	57	47	61	43	na	43
	Spring 2005	54	51	42	38	39	44	45	53	45	53	54
	Summer 2005	55	42	38	51	41	47	48	46	49	55	68
	Autumn 2005	57	35	41	51	46	51	42	30	49	51	39
	Winter 2006	51	40	41	47	40	41	36	43	42	55	31
	Spring 2006	56	44	42	50	32	44	44	46	42	51	33
Los Ramones	Summer 2004	60	39	35	44	39	45	52	na	47	48	39
	Autumn 2004	55	42	36	44	36	46	47	41	45	53	34
	Winter 2005	63	43	38	60	39	46	53	48	40	53	40
	Spring 2005	55	44	40	49	42	45	55	54	41	54	46
	Summer 2005	49	45	58	45	44	47	55	52	42	46	65
	Autumn 2005	51	39	36	42	33	45	45	46	39	47	33
	Winter 2006	46	43	46	46	36	41	46	39	34	36	40
	Spring 2006	59	37	40	53	42	43	48	na	39	46	58
	Grand Mean	55	43	40	48	40	48	48	48	42	49	45
	SEM	0.59	0.48	0.77	0.57	0.58	0.90	0.63	0.94	0.45	0.77	1.40
	Effects	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	0.038	0.514	0.000	0.000	<0.001	<0.001	<0.001	<0.001	<0.001
	Sites (B)	<0.001	<0.001	<0.001	0.025	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	0.050	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.011	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	0.051	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

na= not available; SEM= standard error of the mean; n = 10; P = probability. A. ame= *Acacia amentacea*; C. ere= *Castela erecta*; C. pal= *Celtis pallida*; C. cor= *Croton cortesianus*; F. ang= *Forestiera angustifolia*; K. hum= *Karwinskia humboldtiana*; L. fru= *Leucophyllum frutescens*; L. mac= *Lantana macropoda*; S. cel= *Sideroxylon celastrinum*; P. lae= *Prosopis laevigata*; Z. fag= *Zanthoxylum fagara*.

Table 5.5. Seasonal means of acid detergent fiber (ADF %) in native shrubs from northeastern Mexico.

Site	Season and year	*A. ame*	*C. ere*	*C. pal*	*C. cor*	*F. ang*	*K. hum*	*L. fru*	*L. mac*	*S. cel*	*P. lae*	*Z. fag*
China	Summer 2004	40	26	16	26	22	29	45	27	34	32	16
	Autumn 2004	43	24	16	24	21	41	34	26	27	34	20
	Winter 2005	44	28	19	34	na	36	42	33	28	19	21
	Spring 2005	41	32	20	30	na	22	36	34	29	37	20
	Summer 2005	37	30	16	29	22	26	34	22	32	33	18
	Autumn 2005	41	30	16	30	25	31	34	35	29	35	15
	Winter 2006	34	33	15	33	29	20	41	36	24	27	16
	Spring 2006	35	27	15	28	15	22	32	29	28	29	15
Linares	Summer 2004	46	31	15	31	na	31	36	41	29	39	24
	Autumn 2004	48	32	25	26	na	38	31	39	29	na	22
	Winter 2005	49	32	35	31	27	35	34	38	29	na	20
	Spring 2005	37	35	20	22	24	23	34	36	28	36	24
	Summer 2005	41	29	17	32	22	26	37	29	31	35	17
	Autumn 2005	46	19	28	33	32	33	34	30	33	36	28
	Winter 2006	37	26	24	28	23	22	26	28	24	35	16
	Spring 2006	42	28	20	29	16	26	32	29	26	35	18
Los Ramones	Summer 2004	45	24	17	27	20	26	41	na	33	34	22
	Autumn 2004	38	29	13	26	18	28	36	27	27	34	17
	Winter 2005	51	29	16	26	22	26	37	31	28	36	18
	Spring 2005	41	30	18	31	25	25	38	36	28	39	18
	Summer 2005	40	32	21	28	28	33	43	36	35	37	19
	Autumn 2005	38	28	19	26	22	26	37	32	26	33	17
	Winter 2006	31	31	29	29	20	25	36	26	21	22	26
	Spring 2006	43	25	21	32	21	24	35	na	24	29	21
	Grand Mean	41	29	20	29	23	28	36	32	28	33	20
	SEM	0.6	0.4	0.6	0.4	0.5	0.7	0.5	0.6	0.4	0.6	0.4
	Effects	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	<0.001	<0.001	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Sites (B)	<0.001	0.052	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.051	<0.001	<0.001
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.036	<0.001	<0.001	0.243
	A x B	0.004	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.024	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001

na= not available; SEM= standard error of the mean; n = 10; P = probability. A. ame= *Acacia amentacea*; C. ere= *Castela erecta*; C. pal= *Celtis pallida*; C. cor= *Croton cortesianus*; F. ang= *Forestiera angustifolia*; K. hum= *Karwinskia humboldtiana*; L. fru= *Leucophyllum frutescens*; L. mac= *Lantana macropoda*; S. cel= *Sideroxylon celastrinum*; P. lae= *Prosopis laevigata*; Z. fag= *Zanthoxylum fagara*.

Table 5.6. Seasonal means of lignin (%) in native shrubs from northeastern Mexico.

Site	Season and year	*A. ame*	*C. ere*	*C. pal*	*C. cor*	*F. ang*	*K. hum*	*L. fru*	*L. mac*	*S. cel*	*P. lae*	*Z. fag*
China	Summer 2004	22	14	6	7	11	16	26	10	19	16	6
	Autumn 2004	23	13	5	6	11	21	22	8	14	16	7
	Winter 2005	26	15	8	10	na	21	26	12	15	7	9
	Spring 2005	23	17	9	10	na	13	23	12	15	18	8
	Summer 2005	20	17	6	7	8	14	18	10	16	17	7
	Autumn 2005	22	17	6	9	14	18	20	11	15	18	6
	Winter 2006	20	20	6	10	13	11	26	12	13	12	6
	Spring 2006	21	16	6	8	9	13	20	12	16	18	5
Linares	Summer 2004	26	16	5	9	na	17	21	15	16	16	9
	Autumn 2004	30	16	10	7	na	20	21	14	15	na	8
	Winter 2005	33	16	15	9	13	19	18	13	15	na	7
	Spring 2005	20	18	8	7	14	13	20	19	13	19	8
	Summer 2005	23	17	7	11	11	13	20	9	16	18	7
	Autumn 2005	25	7	10	8	17	13	19	4	15	18	9
	Winter 2006	22	15	9	7	12	12	16	10	15	18	7
	Spring 2006	25	16	8	9	9	14	22	12	13	18	7
Los Ramones	Summer 2004	28	13	7	8	11	15	28	na	19	16	8
	Autumn 2004	20	14	5	6	10	16	22	9	14	14	6
	Winter 2005	34	15	6	10	10	15	22	11	16	16	7
	Spring 2005	23	15	7	10	11	14	20	13	14	19	7
	Summer 2005	23	17	10	9	13	20	30	13	21	19	8
	Autumn 2005	21	16	8	8	13	13	21	12	16	16	8
	Winter 2006	19	18	12	6	10	14	23	10	11	10	13
	Spring 2006	25	14	9	8	11	13	22	na	14	15	7
	Grand Mean	24	15	8	8	12	15	22	11	15	16	8
	SEM	0.48	0.29	0.33	0.18	0.28	0.36	0.39	0.37	0.26	0.36	0.19
	Effects	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	0.003	0.156	0.279	0.044	<0.001	0.001	<0.001	0.008	0.011	0.380
	Sites (B)	<0.001	<0.001	<0.001	0.091	<0.001	0.001	<0.001	0.010	0.002	<0.001	<0.001
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	0.055	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.060	<0.001	<0.001
	A x C	<0.001	<0.001	0.039	<0.001	<0.001	<0.001	0.002	0.487	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

na= not available; SEM= standard error of the mean; n = 10; P = probability. A. ame= *Acacia amentacea*; C. ere= *Castela erecta*; C. pal= *Celtis pallida*; C. cor= *Croton cortesianus*; F. ang= *Forestiera angustifolia*; K. hum= *Karwinskia humboldtiana*; L. fru= *Leucophyllum frutescens*; L. mac= *Lantana macropoda*; S. cel= *Sideroxylon celastrinum*; P. lae= *Prosopis laevigata*; Z. fag= *Zanthoxylum fagara*.

Table 5.7. Seasonal means of hemicellulose (%) in native shrubs from northeastern Mexico.

Site	Season and year	*A. ame*	*C. ere*	*C. pal*	*C. cor*	*F. ang*	*K. hum*	*L. fru*	*L. mac*	*S. cel*	*P. lae*	*Z. fag*
China	Summer 2004	16	13	18	22	18	20	13	19	14	14	14
	Autumn 2004	18	11	22	18	18	26	14	19	15	22	33
	Winter 2005	14	12	19	22	na	23	17	23	12	14	18
	Spring 2005	14	13	22	18	na	19	12	18	15	14	36
	Summer 2005	14	15	20	22	21	20	12	16	14	15	55
	Autumn 2005	12	12	21	16	13	16	10	13	13	15	23
	Winter 2006	13	14	21	18	21	17	10	14	13	16	17
	Spring 2006	16	14	21	19	21	17	13	17	12	15	36
Linares	Summer 2004	15	16	17	19	na	18	12	20	14	20	22
	Autumn 2004	14	16	20	21	na	27	11	21	14	na	22
	Winter 2005	14	16	23	22	18	22	13	23	14	na	23
	Spring 2005	17	16	22	15	15	20	11	17	17	17	30
	Summer 2005	14	13	20	19	19	21	12	18	18	20	51
	Autumn 2005	11	16	13	18	14	18	9	0	15	15	12
	Winter 2006	14	14	17	19	17	19	10	15	17	19	15
	Spring 2006	14	15	22	21	16	18	12	17	16	16	14
Los Ramones	Summer 2004	15	14	18	17	19	18	10	na	13	14	18
	Autumn 2004	17	13	22	19	18	18	11	14	18	18	17
	Winter 2005	13	14	22	34	18	19	16	16	12	17	23
	Spring 2005	14	14	22	19	17	21	17	18	13	15	28
	Summer 2005	9	13	37	17	16	13	11	16	7	9	46
	Autumn 2005	14	12	17	15	11	19	8	14	13	14	16
	Winter 2006	15	12	17	18	16	16	10	13	13	14	14
	Spring 2006	16	12	19	21	20	19	12	na	15	17	37
	Grand Mean	14	14	21	20	17	19	12	16	14	16	26
	SEM	0.2	0.2	0.5	0.4	0.4	0.4	0.3	0.6	0.3	0.3	1.4
	Effects	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	0.352	<0.001	<0.001	<0.001	<0.001	<0.001	0.006	<0.001	<0.001
	Sites (B)	0.008	<0.001	<0.001	0.007	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	0.072	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x C	<0.001	0.891	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

na= not available; SEM= standard error of the mean; n = 10; P = probability. A. ame= *Acacia amentacea*; C. ere= *Castela erecta*; C. pal= *Celtis pallida*; C. cor= *Croton cortesianus*; F. ang= *Forestiera angustifolia*; K. hum= *Karwinskia humboldtiana*; L. fru= *Leucophyllum frutescens*; L. mac= *Lantana macropoda*; S. cel= *Sideroxylon celastrinum*; P. lae= *Prosopis laevigata*; Z. fag= *Zanthoxylum fagara*.

Table 5.8. Seasonal means of cellulose (%) in native shrubs from northeastern Mexico.

Site	Season and year	*A. ame*	*C. ere*	*C. pal*	*C. cor*	*F. ang*	*K. hum*	*L. fru*	*L. mac*	*S. cel*	*P. lae*	*Z. fag*
China	Summer 2004	18	11	9	18	11	13	20	17	14	16	10
	Autumn 2004	21	11	11	19	10	19	12	18	13	18	13
	Winter 2005	18	13	10	24	na	15	16	21	12	13	13
	Spring 2005	18	15	11	20	na	12	14	22	14	19	12
	Summer 2005	17	13	11	22	15	12	16	13	16	16	12
	Autumn 2005	18	13	11	21	11	13	15	23	14	18	8
	Winter 2006	13	13	10	24	16	9	15	23	12	15	10
	Spring 2006	15	11	9	20	6	9	11	17	12	12	10
Linares	Summer 2004	20	15	10	22	na	13	15	26	13	22	15
	Autumn 2004	18	16	15	19	na	19	10	26	13	na	14
	Winter 2005	16	17	20	23	14	16	17	25	14	na	13
	Spring 2005	17	17	12	15	9	10	14	17	14	17	16
	Summer 2005	18	12	10	21	10	13	17	19	15	17	10
	Autumn 2005	21	12	18	24	14	20	15	26	18	17	19
	Winter 2006	14	11	15	21	11	10	9	18	9	18	9
	Spring 2006	18	13	12	20	7	12	10	18	13	17	12
Los Ramones	Summer 2004	17	11	10	19	9	12	13	na	14	18	13
	Autumn 2004	18	15	9	20	8	12	14	18	13	20	11
	Winter 2005	17	15	10	17	12	11	15	21	12	20	11
	Spring 2005	19	16	11	21	15	10	19	24	13	20	12
	Summer 2005	18	15	12	19	14	13	14	23	14	18	12
	Autumn 2005	16	11	10	18	8	12	16	20	11	17	9
	Winter 2006	12	13	17	23	10	11	14	16	12	12	13
	Spring 2006	18	11	12	24	10	11	14	na	10	14	14
	Grand Mean	17	13	12	21	11	13	14	20	13	17	12
	SEM	0.2	0.2	0.4	0.3	0.4	0.3	0.3	0.5	0.2	0.3	0.3
	Effects	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	0.035	<0.001	0.260	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Sites (B)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	0.163	0.205	<0.001	0.050	<0.001	<0.001	<0.001	<0.001
	A x C	<0.001	<0.001	0.099	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

na= not available; SEM= standard error of the mean; n = 10; P = probability. A. ame= *Acacia amentacea*; C. ere= *Castela erecta*; C. pal= *Celtis pallida*; C. cor= *Croton cortesianus*; F. ang= *Forestiera angustifolia*; K. hum= *Karwinskia humboldtiana*; L. fru= *Leucophyllum frutescens*; L. mac= *Lantana macropoda*; S. cel= *Sideroxylon celastrinum*; P. lae= *Prosopis laevigata*; Z. fag= *Zanthoxylum fagara*.

Table 5.9. Seasonal means of dry matter digestibility (DMD %) in native shrubs from northeastern Mexico.

Site	Season and year	*A. ame*	*C. ere*	*C. pal*	*C. cor*	*F. ang*	*K. hum*	*L. fru*	*L. mac*	*S. cel*	*P. lae*	*Z. fag*
China	Summer 2004	50	63	77	68	66	61	58	64	54	59	73
	Autumn 2004	47	64	77	66	68	50	48	65	63	60	70
	Winter 2005	45	61	73	58	na	54	59	59	62	78	68
	Spring 2005	49	57	73	61	na	69	49	57	61	55	71
	Summer 2005	54	59	78	61	69	64	47	67	58	59	74
	Autumn 2005	49	59	76	61	64	60	44	55	61	56	77
	Winter 2006	56	56	76	57	59	69	51	54	65	67	72
	Spring 2006	55	62	79	64	74	69	44	63	61	63	79
Linares	Summer 2004	44	57	76	59	na	59	49	48	60	52	66
	Autumn 2004	43	57	67	65	na	53	42	51	60	na	67
	Winter 2005	43	57	59	59	63	55	47	54	60	na	69
	Spring 2005	53	53	72	70	65	68	45	54	62	56	66
	Summer 2005	49	61	75	59	68	65	48	63	60	57	74
	Autumn 2005	44	70	64	59	58	57	42	60	58	56	63
	Winter 2006	53	64	69	62	66	68	36	62	65	55	74
	Spring 2006	48	61	74	62	73	65	44	62	64	58	72
Los	Summer 2004	44	65	76	63	69	63	52	na	55	58	68
	Autumn 2004	52	60	77	65	71	62	47	63	62	58	73
	Winter 2005	41	59	81	65	67	64	53	59	61	55	73
	Spring 2005	49	58	74	61	64	67	56	56	61	52	72
	Summer 2005	52	58	73	62	62	58	55	55	54	55	71
	Autumn 2005	52	61	74	63	67	63	45	58	64	58	73
	Winter 2006	59	58	61	61	68	64	46	65	68	74	64
	Spring 2006	48	66	73	60	68	67	48	na	66	63	72
	Grand Mean	49	60	73	62	66	62	48	59	61	59	71
	SEM	0.98	0.79	1.14	0.62	0.98	1.18	1.18	1.09	0.70	1.37	0.79
	Effects	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Sites (B)	<0.001	0.017	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.060	<0.001	<0.001
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.583	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	0.073	<0.001	<0.001	<0.001	<0.001	0.067	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001

na= not available; SEM= standard error of the mean; n = 10; P = probability. A. ame= *Acacia amentacea*; C. ere= *Castela erecta*; C. pal= *Celtis pallida*; C. cor= *Croton cortesianus*; F. ang= *Forestiera angustifolia*; K. hum= *Karwinskia humboldtiana*; L. fru= *Leucophyllum frutescens*; L. mac= *Lantana macropoda*; S. cel= *Sideroxylon celastrinum*; P. lae= *Prosopis laevigata*; Z. fag= *Zanthoxylum fagara*.

Table 5.10. Seasonal means of digestible energy (DE Kcal g^{-1} DM) in native shrubs from northeastern Mexico.

Site	Season and year	*A. ame*	*C. ere*	*C. pal*	*C. cor*	*F. ang*	*K. hum*	*L. fru*	*L. mac*	*S. cel*	*P. lae*	*Z. fag*
China	Summer 2004	2.4	3.1	3.6	3.2	3.1	2.9	2.1	3.0	2.6	2.8	3.4
	Autumn 2004	2.3	2.9	3.6	3.1	3.2	2.4	2.6	3.0	3.0	2.8	3.3
	Winter 2005	2.2	2.8	3.4	2.8	na	2.6	2.3	2.8	2.9	3.6	3.2
	Spring 2005	2.4	2.8	3.4	2.9	na	3.2	2.5	2.7	2.9	2.6	3.3
	Summer 2005	2.6	2.7	3.6	2.9	3.2	3.0	2.6	3.1	2.8	2.8	3.4
	Autumn 2005	2.4	2.9	3.5	2.9	3.0	2.8	2.6	2.6	2.9	2.7	3.6
	Winter 2006	2.7	2.8	3.5	2.7	2.8	3.2	2.3	2.6	3.1	3.1	3.4
	Spring 2006	2.6	3.1	3.7	3.0	3.5	3.2	2.7	3.0	2.9	3.0	3.7
Linares	Summer 2004	2.1	3.0	3.5	2.8	na	2.8	2.5	2.3	2.8	2.5	3.1
	Autumn 2004	2.1	3.0	3.2	3.0	na	2.5	2.8	2.5	2.8	na	3.2
	Winter 2005	2.1	2.9	2.8	2.8	3.0	2.6	2.6	2.6	2.8	na	3.2
	Spring 2005	2.5	2.7	3.3	3.3	3.0	3.2	2.6	2.6	2.9	2.7	3.1
	Summer 2005	2.4	2.8	3.5	2.8	3.2	3.1	2.5	3.0	2.9	2.7	3.5
	Autumn 2005	2.2	2.8	3.0	2.8	2.7	2.7	2.7	2.8	2.7	2.7	3.0
	Winter 2006	2.5	2.7	3.2	2.9	3.1	3.2	3.0	2.9	3.1	2.6	3.4
	Spring 2006	2.3	2.9	3.4	2.9	3.4	3.0	2.7	2.9	3.0	2.8	3.4
Los	Summer 2004	2.2	2.7	3.5	3.0	3.2	3.0	2.3	na	2.6	2.7	3.2
	Autumn 2004	2.5	2.7	3.6	3.0	3.3	2.9	2.5	2.9	2.9	2.8	3.4
	Winter 2005	2.0	2.7	3.7	3.1	3.1	3.0	2.6	2.8	2.9	2.6	3.4
	Spring 2005	2.4	2.5	3.4	2.9	3.0	3.1	2.5	2.7	2.9	2.5	3.4
	Summer 2005	2.5	2.9	3.4	2.9	2.9	2.7	2.2	2.6	2.6	2.6	3.3
	Autumn 2005	2.5	3.3	3.4	3.0	3.1	3.0	2.5	2.7	3.0	2.8	3.4
	Winter 2006	2.8	3.0	2.9	2.9	3.2	3.0	2.5	3.1	3.2	3.4	3.0
	Spring 2006	2.3	2.9	3.4	2.8	3.2	3.1	2.6	na	3.1	3.0	3.3
	Grand Mean	2.4	2.9	3.4	2.9	3.1	2.9	2.5	2.8	2.9	2.8	3.3
	SEM	0.04	0.03	0.05	0.03	0.04	0.05	0.04	0.05	0.03	0.06	0.03
	Effects	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Sites (B)	<0.001	0.017	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	0.072	<0.001	<0.001
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.568	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	0.100	<0.001	<0.001	<0.001	<0.001	0.066	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001

na= not available; SEM= standard error of the mean; n = 10; P = probability. A. ame= *Acacia amentacea*; C. ere= *Castela erecta*; C. pal= *Celtis pallida*; C. cor= *Croton cortesianus*; F. ang= *Forestiera angustifolia*; K. hum= *Karwinskia humboldtiana*; L. fru= *Leucophyllum frutescens*; L. mac= *Lantana macropoda*; S. cel= *Sideroxylon celastrinum*; P. lae= *Prosopis laevigata*; Z. fag= *Zanthoxylum fagara*.

Table 5.11. Seasonal means of metabolizable energy (ME Mcal Kg^{-1} DM) in native shrubs from northeastern Mexico.

Site	Season and year	*A. ame*	*C. ere*	*C. pal*	*C. cor*	*F. ang*	*K. hum*	*L. fru*	*L. mac*	*S. cel*	*P. lae*	*Z. fag*
China	Summer 2004	2.0	2.4	2.9	2.6	2.5	2.4	1.7	2.5	2.1	2.3	2.8
	Autumn 2004	1.9	2.5	2.9	2.5	2.6	2.0	2.2	2.5	2.4	2.3	2.7
	Winter 2005	1.8	2.4	2.8	2.3	na	2.1	1.9	2.3	2.4	3.0	2.6
	Spring 2005	2.0	2.2	2.8	2.4	na	2.6	2.1	2.2	2.3	2.2	2.7
	Summer 2005	2.1	2.3	3.0	2.4	2.6	2.5	2.1	2.6	2.3	2.3	2.8
	Autumn 2005	2.0	2.3	2.9	2.4	2.5	2.3	2.1	2.2	2.4	2.2	2.9
	Winter 2006	2.2	2.2	2.9	2.2	2.3	2.7	1.9	2.1	2.5	2.6	2.8
	Spring 2006	2.1	2.4	3.0	2.5	2.8	2.6	2.3	2.4	2.4	2.4	3.0
Linares	Summer 2004	1.8	2.2	2.9	2.3	na	2.3	2.0	1.9	2.3	2.1	2.5
	Autumn 2004	1.7	2.2	2.6	2.5	na	2.1	2.3	2.0	2.3	na	2.6
	Winter 2005	1.7	2.2	2.3	2.3	2.4	2.1	2.2	2.1	2.3	na	2.7
	Spring 2005	2.1	2.1	2.7	2.7	2.5	2.6	2.1	2.1	2.4	2.2	2.6
	Summer 2005	2.0	2.4	2.9	2.3	2.6	2.5	2.1	2.4	2.3	2.2	2.8
	Autumn 2005	1.8	2.7	2.5	2.3	2.3	2.2	2.2	2.3	2.3	2.2	2.5
	Winter 2006	2.1	2.5	2.6	2.4	2.5	2.6	2.5	2.4	2.5	2.2	2.8
	Spring 2006	1.9	2.4	2.8	2.4	2.8	2.5	2.2	2.4	2.5	2.3	2.8
Los	Summer 2004	1.8	2.5	2.9	2.4	2.7	2.4	1.9	na	2.2	2.3	2.6
	Autumn 2004	2.0	2.3	2.9	2.5	2.7	2.4	2.1	2.4	2.4	2.3	2.8
	Winter 2005	1.6	2.3	3.1	2.5	2.6	2.5	2.1	2.3	2.4	2.2	2.8
	Spring 2005	1.9	2.3	2.8	2.4	2.5	2.6	2.1	2.2	2.4	2.1	2.8
	Summer 2005	2.0	2.3	2.8	2.4	2.4	2.3	1.8	2.2	2.1	2.1	2.7
	Autumn 2005	2.1	2.4	2.8	2.4	2.6	2.4	2.0	2.3	2.5	2.3	2.8
	Winter 2006	2.3	2.3	2.4	2.4	2.6	2.5	2.1	2.5	2.6	2.8	2.5
	Spring 2006	1.9	2.5	2.8	2.3	2.6	2.6	2.1	na	2.5	2.4	2.7
	Grand Mean	1.9	2.3	2.8	2.4	2.6	2.4	2.1	2.3	2.4	2.3	2.7
	SEM	0.03	0.03	0.04	0.02	0.03	0.04	0.03	0.04	0.03	0.05	0.03
	Effects	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Sites (B)	<0.001	0.014	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.059	<0.001	<0.001
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.580	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	0.101	<0.001	<0.001	<0.001	<0.001	0.114	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001

na= not available; SEM= standard error of the mean; n = 10; P = probability. A. ame= *Acacia amentacea*; C. ere= *Castela erecta*; C. pal= *Celtis pallida*; C. cor= *Croton cortesianus*; F. ang= *Forestiera angustifolia*; K. hum= *Karwinskia humboldtiana*; L. fru= *Leucophyllum frutescens*; L. mac= *Lantana macropoda*; S. cel= *Sideroxylon celastrinum*; P. lae= *Prosopis laevigata*; Z. fag= *Zanthoxylum fagara*.

Table 5.12. Seasonal means of insoluble neutral detergent fiber (INDF g Kg^{-1} DM) in native shrubs from northeastern Mexico.

Site	Season and year	*A. ame*	*C. ere*	*C. pal*	*C. cor*	*F. ang*	*K. hum*	*L. fru*	*L. mac*	*S. cel*	*P. lae*	*Z. fag*
China	Summer 2004	9.7	34.6	47.2	32.1	36.0	20.7	3.5	30.9	18.9	24.7	50.1
	Autumn 2004	3.2	38.3	44.3	39.2	36.4	1.7	17.5	33.5	31.6	14.1	26.4
	Winter 2005	2.7	31.4	41.1	19.9	na	6.3	2.1	20.2	32.9	46.7	38.6
	Spring 2005	9.6	24.5	35.8	29.0	na	33.5	15.8	23.0	28.5	18.8	23.4
	Summer 2005	16.5	25.2	45.8	28.2	35.7	27.1	22.2	39.5	25.3	23.1	8.2
	Autumn 2005	11.4	28.2	44.0	32.0	35.3	23.2	23.1	28.3	30.7	19.5	43.4
	Winter 2006	19.6	20.8	44.6	25.5	23.5	38.0	9.6	25.1	37.2	32.1	47.0
	Spring 2006	14.8	30.9	45.2	32.3	41.8	35.5	22.4	29.4	30.9	25.0	30.5
Linares	Summer 2004	0.8	23.8	49.7	28.1	na	21.5	17.1	11.0	28.5	11.2	31.6
	Autumn 2004	5.2	23.5	31.6	32.5	na	1.6	24.7	12.2	28.4	na	34.2
	Winter 2005	9.7	23.2	13.4	25.4	28.1	11.1	22.4	13.3	28.4	na	36.8
	Spring 2005	12.8	17.7	36.4	42.4	34.3	30.9	21.8	14.9	29.2	14.8	25.1
	Summer 2005	9.6	27.5	42.0	25.6	35.1	27.4	18.5	31.3	22.2	13.2	11.9
	Autumn 2005	4.7	44.5	36.1	27.8	24.2	23.0	25.8	53.4	23.2	17.9	38.9
	Winter 2006	14.2	32.0	36.4	32.5	35.1	33.7	34.8	34.2	29.7	14.9	49.8
	Spring 2006	5.6	27.9	36.7	27.6	45.9	28.6	20.5	28.8	32.1	17.3	47.5
Los Ramones	Summer 2004	2.9	35.5	44.5	35.2	37.5	27.7	7.9	na	21.4	22.7	39.3
	Autumn 2004	12.2	30.5	46.6	36.9	40.8	24.7	18.0	36.3	27.4	20.3	46.6
	Winter 2005	10.1	29.2	43.1	17.0	37.4	26.4	11.4	28.4	30.8	17.3	40.0
	Spring 2005	9.0	27.9	39.6	27.9	34.0	28.0	11.3	20.5	31.5	14.2	33.3
	Summer 2005	14.7	25.0	18.8	32.7	29.3	20.3	2.8	22.2	24.7	21.4	14.1
	Autumn 2005	14.4	31.5	42.7	37.6	41.2	28.8	21.3	29.1	32.2	23.4	45.6
	Winter 2006	21.7	26.7	28.3	34.2	40.8	32.3	18.3	37.7	42.0	40.8	33.9
	Spring 2006	3.8	36.2	38.1	25.9	34.2	30.8	17.3	na	33.5	25.7	21.5
	Grand Mean	9.9	29.0	38.8	30.3	35.3	24.3	17.1	27.4	29.2	21.8	34.1
	SEM	1.1	1.2	1.8	1.2	1.3	2.0	1.6	2.2	1.0	1.9	2.5
	Effects	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
	Year (A)	<0.001	0.001	0.074	0.363	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Sites (B)	<0.001	<0.001	<0.001	0.023	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.059
	Seasons (C)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.019	0.001	<0.001	<0.001
	B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	A x B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001

na= not available; SEM= standard error of the mean; n = 10; P = probability. A. ame= *Acacia amentacea*; C. ere= *Castela erecta*; C. pal= *Celtis pallida*; C. cor= *Croton cortesianus*; F. ang= *Forestiera angustifolia*; K. hum= *Karwinskia humboldtiana*; L. fru= *Leucophyllum frutescens*; L. mac= *Lantana macropoda*; S. cel= *Sideroxylon celastrinum*; P. lae= *Prosopis laevigata*; Z. fag= *Zanthoxylum fagara*.

6. CONCLUSIÓN GENERAL

Los resultados del presente trabajo indicaron que el contenido de macro (Ca, Mg, Na y K) y micro nutrientes (Fe y Mn) de *Castela erecta texana, Celtis pallida, Forestiera angustifolia, Lantana macropoda* and *Zanthoxylum fagara*, es suficiente para el mantenimiento del venado cola blanca adulto en general. De todos los nutrientes minerales, el más crítico es el fósforo que fue bajo para la mayor parte de las especies analizadas, especialmente durante las estaciones de sequía (invierno y primavera). Sólo *Lantana macropoda* y *Forestiera angustifolia* presentaron un contenido de Zn suficiente para los requerimientos del venado cola blanca. Las especies estudiadas no contienen las cantidades suficientes de Cu en conjunto durante el invierno y primavera.

La tendencia anterior fue generalizada para los tres sitios de estudio, sin embargo, los mayores valores de todos los macro y micro nutrientes fueron registrados para el sitio Linares, atribuible a la mayor precipitación histórica del sitio. Dicha argumento encuentra soporte en que los mayores registros en este estudio estuvieron influidos positivamente por la mayor precipitación registrada en el segundo año (año en que ocurrió el Huracán Emily durante el verano de 2005).

Las interacciones positivas entre el contenido mineral y los registros de temperatura y precipitación sugieren que las arbustivas nativas se desarrollan bien con los déficits de precipitación y temperaturas extremas durante las estaciones secas o húmedas.

La composición química de once especies ramoneadas por el venado cola blanca le brindan marginalmente, la proteína cruda y la energía metabolizable para mantenimiento, pero ésta última podría estar más baja de lo requerido para los propósitos cinegéticos. Este potencial es marginal debido a que existen variaciones en algunas estaciones es menor al requerimiento del venado cola blanca, como por ejemplo en invierno. Aquellas especies con el mayor contenido de proteína cruda (*F. angustifolia* and *P. laevigata*) también son especies con alto contenido de pared celular mayor, lo que disminuye la degradabilidad del forraje y consecuentemente en la digestibilidad en el rumen.

El contenido de pared celular podría representar un límite para aprovechar las ventajas nutricionales de las arbustivas estudiadas. Las especies con mayor contenido de proteína cruda y energía fueron *C. pallida* y *F. angustifolia*, lo cual pone de manifiesto la importancia de la diversidad debido a que estas especies tienen diferente ciclo de desarrollo a lo largo del año, incluso durante los largos periodos de sequía, los venados tienen acceso a energía y proteína cruda.

Por lo anterior, la hipótesis planteada (Once especies arbustivas nativas consumidas por el venado cola blanca (*Odocoileus virginianus*) cubren los requerimientos nutricionales de esta especie en los sitios de estudio a lo largo del año) se rechaza ya que las once especies no cuentan con las cualidades nutritivas para el venado cola blanca a lo largo del año. Sin embargo, algunas de ellas muestran mayores porcentajes en algunos parámetros de nutrición en distintas estaciones, lo que enfatiza la importancia de la diversidad en el manejo de hábitat del venado cola blanca en la región.

Para contar con un perfil nutricional completo de estas especies, puede partirse de aquellas que mostraron las mejores cualidades en este estudio para determinar además su contenido de compuestos secundarios y digestibilidad. Eventualmente, será necesario estudiar las particularidades del sistema digestivo del venado cola blanca para explicar su habilidad para aprovechar fuentes de proteína, minerales y energía que el ganado doméstico no consume.

7. PUBLICACIONES EMANADAS Y PARTICIPACIÓN EN CONGRESOS

7.1. Libro

Ramírez, L.R.G., Alvarado, M.S., González, R.H.2010. Mineral content in browse plant growing at northeastern Mexico. Minerals in native shrubs from northeastern Mexico LAP Lambert Academic Publishing. U.S.A. 88 p. ISBN: 9783843355605. (Publicado).

7.2. Aceptados por la casa editorial

Alvarado, M.S., Ramírez, L.R.G., González, R.H., Cantú, S.I., Gómez, M.M.V., Cotera, C.M., Jurado, Y.E. and Domínguez, G.T.G. Macro mineral content in five shrubs browsed by White-tailed deer (*Odocoileus virginianus texanus*), northeastern Mexico. Journal of Animal and Veterinary Advances. (http://www.medwelljournals.com).

Alvarado, M.S., Ramírez-Lozano, R.G., González-Rodríguez, H., Cantú-Silva, I., Jurado-Ybarra, E., Cotera-Correa, M., Domínguez-Gómez, T.G. Trace elements in native shrubs consumed by white-tailed deer (*Odocoileus virginianus* texanus*)* in the northeast of Mexico. Journal of Applied Animal Research. (http://www.tandfonline.com).

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7.3. Memorias *in* extenso

Alvarado, M.S., Ramírez, L.R.G., González, R.H., Cantú, S.I., Jurado, Y.E., Cotera, C.M., Domínguez, GT.G. 2011. Contenido mineral de 11 especies del Matorral Espinoso Tamaulipeco, alimenticias para el venado cola blanca. X Congreso Mexicano de Recursos Forestales. Del 22 al 25 de noviembre de 2011. Pachuca, Hidalgo, México. Pp: 1-7.

7.4. Presentaciones en Congresos

Alvarado, M.S., Ramírez, L.R.G., González, R.H., Cantú, S.I., Jurado, Y.E., Cotera, C.M., Domínguez, GT.G. Macronutrimentos en arbustivas consumidas por el venado cola blanca en el Noreste de Nuevo León. III Congreso Mexicano de Ecología. Del 3 al 7 de abril del 2011. Boca del Río, Veracruz, México.

Alvarado, M.S., Ramírez, L.R.G., González, R.H., Cantú, S.I., Jurado, Y.E., Cotera, C.M., Domínguez, GT.G. Micronutrimentos en arbustivas consumidas por el venado cola blanca en el Noreste de Nuevo León. III Congreso Mexicano de Ecología. Del 3 al 7 de abril del 2011. Boca del Río, Veracruz, México.

Alvarado, M.S., Uvalle, S.J.I., Ramírez, L.R.G., González, R.H., Cantú, S.I., Jurado, Y.E., Cotera, C.M., Domínguez, GT.G. Contenido de macro y micro nutrimentos del suelo en tres comunidades de vegetación, Noreste de México. X Congreso Mexicano de Recursos Forestales. Del 22 al 25 de noviembre de 2011. Pachuca, Hidalgo, México.