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Effect of prescribed fire on forage production and nutritive value of the perennial grass *Saccharum griffithii*

Efecto del fuego controlado en la producción de forraje y valor nutritivo de la gramínea perenne *Saccharum griffithii*

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Abstract. The effect of fire on growth and nutritive value of *Saccharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr. hybrid, a low palatable perennial grass in the semi-arid region of the highlands of Balochistan, Pakistan, was evaluated during 2008 and 2009. Prescribed fire treatments were applied in February 2008 and 2009 at the dormant stage of vegetation. Different growth parameters (tiller height, tiller number/plant), forage production (fresh, dry) and nutritive value (crude protein, ash) were compared with control (unburnt) plots. Fire increased the number of tillers, and the fresh and dry forage production in both years. Fire also improved the crude protein contents. Prescribed fire at the dormant stage of vegetation can be used as a vegetation tool to improve the forage quality and quantity of the less preferred grass species *Saccharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr. hybrid.

Keywords: Tiller growth; Fire, Biomass.

Resumen. Se evaluó el efecto del fuego sobre el crecimiento y valor nutritivo del híbrido de *Saccharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr., una gramínea perenne de baja palatabilidad en la región semiárida de las altas montañas de Balochistan, Pakistan, durante 2008 y 2009. Se aplicaron tratamientos de fuego prescripto en Febrero 2008 y 2009 en el estado de reposo de la vegetación. Se compararon diferentes parámetros con parcelas control (no quemadas): parámetros de crecimiento (altura de macollas, número de macollas/planta), producción de forraje (fresco, seco) y valor nutritivo (proteína cruda, cenizas). El fuego incrementó el número de macollas, y la producción de forraje fresco y seco en ambos años. El fuego también aumentó los contenidos de proteína cruda. El fuego prescripto en el estado de reposo de la vegetación se puede usar como una herramienta para mejorar la calidad y cantidad de forraje de la especie de gramínea híbrido menos preferida *Saccharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr.

Palabras clave: Crecimiento de macollas; Fuego; Biomasa.

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INTRODUCTION

Grassland ecosystems have high carbon storage in the soil, and are a potential carbon sink (White et al., 2000; Bronson et al., 2004). Perennial grasses are a fundamental unit of grassland ecosystem functioning (Van Oudtshoom, 2002). The low and unreliable rainfall in arid and semi-arid areas causes enormous fodder flow problems (Snyman, 1998). Grazing and fire are two common disturbances in many semi-arid shrub/grass ecosystems, which have a major impact on the removal of plant tissues (Pelaez et al., 2009). A high capacity for new tiller formation and high tiller growth rate after foliage removal are critical to: (1) determine a rapid re-establishment of a photosynthetic canopy, (2) permit perennial grasses to tolerate defoliation, and (3) maintain their status in the community (Caldwell et al., 1981). Tiller height, number and size of leaves are growth components that may contribute to the re-establishment of a photosynthetic surface area (Becker et al., 1997).

Dormant season fires are used for managing rangelands to increase the biomass of plants. Burning can stimulate plant re-growth, and increase biomass production, palatability, and nutrient content of grasses (Mohammad et al., 1992; Snyman, 2003; Hartley et al., 2007). Prescribed fire can increase the biomass of herbaceous plants (Jacobs & Sheley 2003; MacDonald el al., 2007; Vermeire et al., 2011), including perennials (Jacobs & Sheley 2003; Vermeire et al., 2011). Jacobs and Sheley (2003) found that prescribed fire of *Linaria dalmatica* (L.) in a rangeland of *Artemisia tridentata/Agropyron spicatum* habitat increased its biomass and seed production. However, first year grazing after prescribed fire at the early stages of plant growth may reduce axillary bud number and viability, and therefore plant biomass (Pelaez et al., 2009; Waterman & Vermeire 2011). Depending on the level and timing of the prescribed fire treatment, the impact of fire on grasslands can be either beneficial or detrimental (Gillespie & Allen, 2004). Soil physical, chemical and biochemical properties are also affected by the intensity and frequency of fire (Marco & Prieto, 2008). Sawadogo et al. (2005) found that early season fire reduced biomass of perennials, and increased biomass of annuals, in savanna woodlands, although the effect was not significant. MacDonald et al. (2007) found that fire reduced the biomass of the annual weed *Centaurea maculosa*, and increased the biomass of native grasses in the river bank of Grand River in western Michigan. Therefore, prescribed fire may be a good strategy to increase the biomass of herbaceous vegetation in arid and semiarid rangelands.

Cymbopogon jwarancusa and *Chrysopogon aucheri* are the dominant perennial grasses in the highlands of Balochistan. The productivity of grasses in Balochistan is declining due to unplanned grazing and over-exploitation of desirable plant resources. Palatable grass species like *Chrysopogon aucheri* are being replaced by the less palatable grass *Cymbopogon jwarancusa* and other un-palatable shrub species (Ahmad & Islam, 2010). The rangelands of Balochistan are the major free feed resource for small ruminants, and they also provide many ecological and environmental services. Improving the grazing potential and utilization of less palatable grass species, like S*accharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr. hybrid may be one of the options to overcome the problem of livestock forage availability, particularly during the winter months. S*accharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr. hybrid is a perennial grass, and is commonly found in the highlands of Balochistan. This grass has a low palatability but provides grazing to ruminants in early spring, when the existing biomass is mostly comprised by succulents. This grass is also collected by pastoralists either in early spring or summer season according to the rainfall distribution, and used for stale feeding during the winter season by mixing it with other dry crop residues or alfalfa. At various sites, it was observed that the new growth is hampered by the accumulation of dead plant material.

The present study was conducted to determine the short-term (2 years) impact of prescribed fire on growth, production and nutritive value of S*accharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr. hybrid in the highlands of Balochistan. This study will provide an insight into the efficacy of prescribed fire to increase the quality and quantity of forage of this grass species to domestic ruminants.

MATERIALS AND METHODS

Study area. The study was conducted at the Tomagh Range and Livestock Research Station of the Arid Zone Research Centre near Sanjawi, Ziarat District (30° 15' 44.4" N, 68° 27' 38.36" E). The study area comprised more than 10000 ha which was closed to grazing in 1998. The study site has a Mediterranean climate. The herbaceous layer is dominated by grasses (*Cymbopogan jwarancusa*, C*hrysopogan aucheri*, *Tetrapogon villosa)*, and herbs (*Cousinia stocksii, Peganum harmala, Pulicaria crispa).* Component species of the shrub layer are *Prunus eburnea, Budddleja crispa, Nepeta cataria, Perwoskis atriplicifolia, Salvia cabulica* and *Olea ferruginea*. Annual mean temperatures are is 32 °C in June and 1 °C in January. Average annual precipitation is 250 mm, which occurs mainly in winter, and occasionally during summer months.

Experimental design and fire treatment. The experimental layout was a Completely Randomized Block Design (CRBD) with three replications per treatment. The study was conducted on 6 plots; each plot was 4 x 10 m in size. Three plots were randomly selected for the fire treatment. Fire was applied with a conventional method (no fire-intensity control) in 2008 and 2009. The plots were protected from grazing during that period. Burning was carried out at the end of February, time when the grasses are dry.

Analysis of plant morphological traits and biomass production. Height; total green tiller length; number of live and dead tillers/plant; fresh and dead forage production, and dead plant material were measured after fire every 3 months during the 2008 and 2009 growing seasons. Grass biomass was measured in each plot using a weighing scale. A one m^2 quadrat was randomly thrown into each study plot, and the standing grass that fell within the quadrat was clipped and measured (Kent & Coker, 1992). Fifteen quadrats were harvested on each treatment, and the averages (of each sampled plot) were used for data analysis.

Chemical analysis of plants. Plants were also randomly sampled from burn and unburned plots for chemical analysis. Plant samples were oven-dried at 60 °C for 48 h. Green leaf blades were sorted, ground (to pass through a 1-mm sieve), and analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid-unhydrolizable fraction (AUF, previously called lignin) (Goering & Van Soest, 1970); N measurements were made by the semi-micro Kjeldahl method, while crude protein (CP) was calculated as:

Crude protein = N (nitrogen) x 6.25. (1)

Statistical analysis. All data were subjected to assessment of a normal distribution with the Shapiro-Wilk test. A log transformation was made using SAS (SAS Institute Inc. 2009). Mean differences between seasons, years and treatments were tested for each parameter using the least significance difference (LSD) test after using the PROC GLM function of SAS.

RESULTS

Rainfall during the study period varied between 107.4 and 277 mm, with months during the 2-year-study period which were above the long-term average of 300 mm for the study area (Fig. 1). The effect of burning on tiller height was significant ($p<0.0000$; Table 1), the interactions of season and year x treatment were also significant ($p<0.001$; Table 1). The length of alive tillers of S*accharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr. hybrid was greater in unburnt than in burnt plants ($p<0.05$; Fig. 2).

The effect of fire on number of tillers per plant was significant ($p<0.0000$; Table 1); the interactions of season and year with this treatment were also significant ($p<0.0000$; Table 1). The number of tillers was higher in burnt than in un-burnt plants during most of the sampling dates.

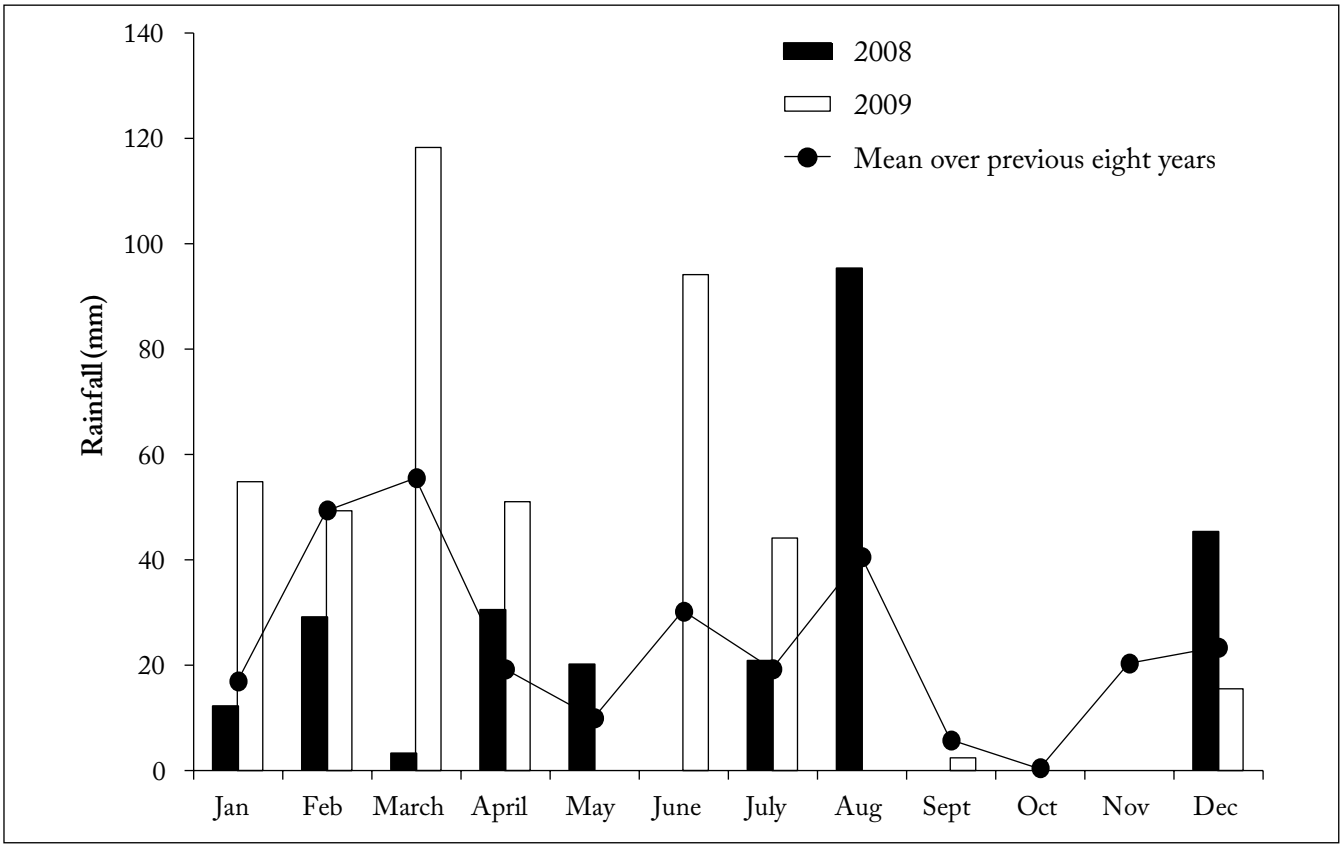

Fig. 1. Monthly rainfall during 2008 and 2009, and average of previous eight years.
Fig. 1. Lluvia mensual durante 2008 y 2009, y promedio de los ocho años previos.

Table 1. ANOVA from a CRBD, split-split plot design, of the pooled data over two years (2008 and 2009), indicating significance of results between burnt *versus* unburnt treatments. Factors were: Season, Treatment x Season, and Treatment x Year interactions of various variables.
Tabla 1. ANOVA de un diseño de bloques completamente al azar, diseño de parcelas divididas-divididas, de los datos agrupados de los dos años (2008 y 2009) indicando significancia de los resultados entre los tratamientos quemado y no quemado. Los Factores fueron: Estación, Tratamiento x Estación, y Tratamiento x Año de las variables.

Variable \ Treatment	Per treatment significance between over two years	Per treatment significance over seasons (the two study years were pooled)	Treatment x Season interaction (the two study years were pooled)	Treatment x Year interaction
Plant height	p = 0.0029	p = 0.0000	p = 0.0000	p = 0.0000
Number of live tillers per plant	p = 0.0000	p = 0.0000	p = 0.0000	p = 0.0000
Number of dead tillers per plant	p = 0.0000	p = 0.0000	p = 0.0000	p = 0.0000
Fresh forage production	p = 0.0001	p = 0.0000	p = 0.0000	p = 0.0000
Dry forage production	p = 0.0002	p = 0.0000	p = 0.0000	p = 0.0000
Accumulated above-ground dead material	p = 0.0001	p = 0.0000	p = 0.0000	p = 0.0000

The effect of fire on the production of the above-ground fresh and dry biomasses was significant (p<0.0001; Table 1). The interactions between season and year with these treatments were also significant (p<0.0000; Table 1). Over the first and second seasons following fire, biomass production was higher on burnt than on control plants of S*accharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr. (p<0.01; Table 1; Fig. 2).

The effect of fire was significant (p<0.0001; Table 1) on accumulation of dead tissue; the interactions between season and year with this treatment were also significant (p<0.0000; Table 1). Fire decreased the dead material during both growing seasons (Fig. 2). The amount of dead material was higher at the first harvest, decreased in the middle, and started accumulating as the dry season proceeded (Fig. 2). As expected, in burnt plots, a decrease in dead material after fire increased the fresh forage production as a result of the better fresh growth of new tillers.

Differences were observed in crude protein contents between burnt and unburnt plots (Table 2). Fiber and AUF contents were numerically higher in unburnt than in burnt plots, whereas CP content was higher in completely burnt plots.

DISCUSSION

Treatment of fire to *Saccharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr. hybrid plants caused an increase in the number of tillers. As expected, in burnt plots, a decrease in dead material after fire increased the fresh forage production due to the better fresh growth of tillers. One of the effects of fire on plants, i.e. sprouting after burning, appears to increase the vigor and growth rate of plants. This response could be caused, at least partially, by an increase nutrient availability due to ashes, and a temporary removal of competition from other plants (Whelan, 1995).

Table 2. Chemical analysis of *Saccharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr. hybrid (%).
Tabla 2. Análisis químico (%) del híbrido *Saccharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr.

Treatments	Crude protein	Crude fiber	Total ash	Ether extract	ADF	NDF	AUF (previously called lignin)
***Saccharum griffithii* Unburnt (dead plant material)**	4.28	38.06	8.21	3.49	47.6	77.3	4.2
***Saccharum griffithii* Unburnt (new plant material)**	6.19	35.73	7.43	2.77	43.5	77.0	4.3
***Saccharum griffithii* Burnt (new plant material)**	8.07	34.15	6.40	2.45	42.2	76.1	4.3

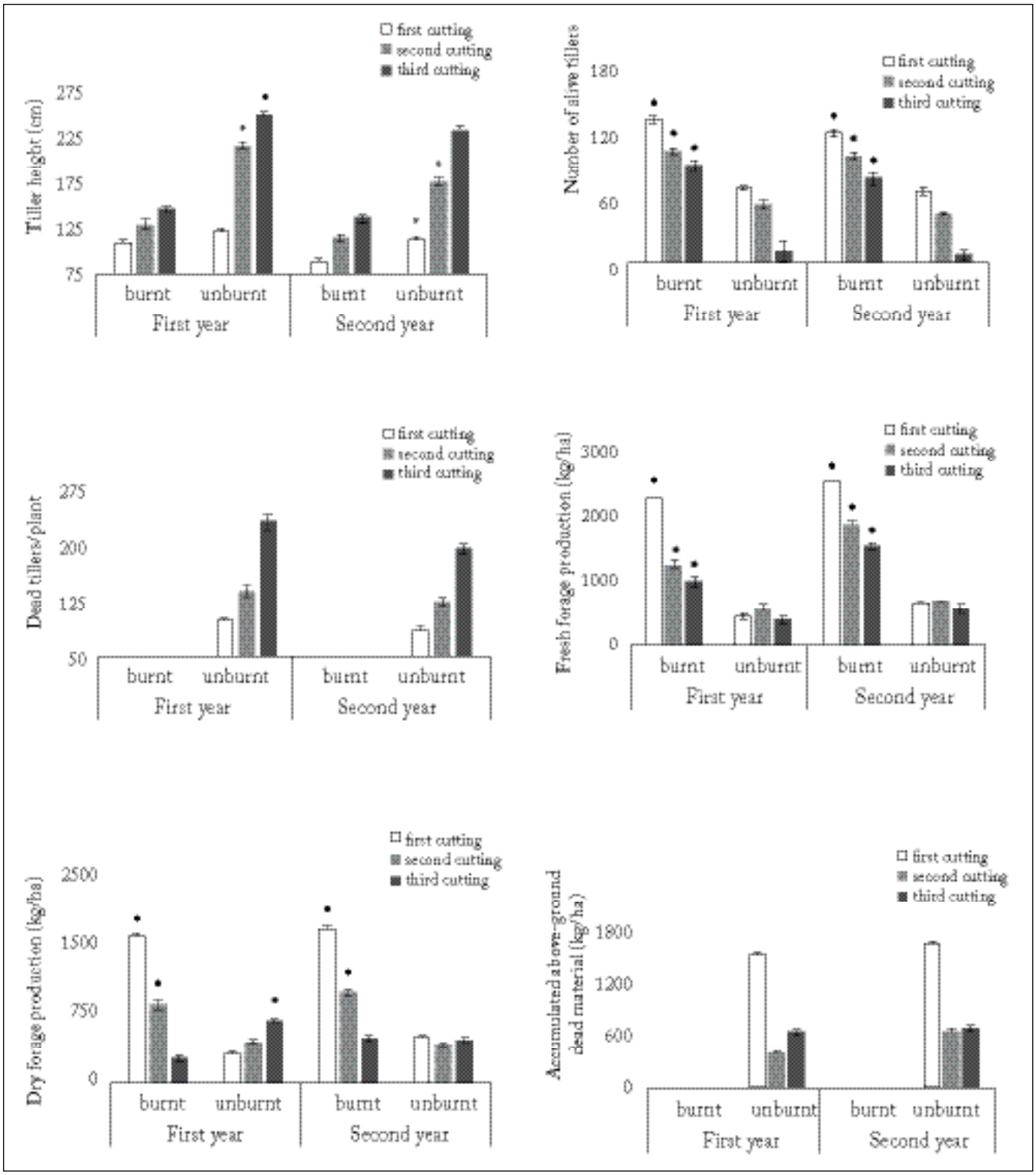

Fig. 2. Tiller height (cm), number of alive tillers per plant, number of dead tillers per plant, fresh forage production (kg/ha), dry forage production (kg/ha), and accumulated above-ground dead material (kg/ha) of *Saccharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr. hybrid on the burnt and unburnt treatments.

Fig. 2. Altura de las macollas (cm), número de macollas vivas por planta, número de macollas muertas por planta, producción de forraje fresco (kg/ha), producción de forraje seco (kg/ha), y material muerto aéreo acumulado (kg/ha) del híbrido *Saccharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr. en las parcelas quemadas y no quemadas.

The average dead material in the unburnt plots during one growing season was almost 800 kg/ha in this study. This is similar (750 kg/ha) to the amount reported for a semi-arid *Astrebla pectinata* grassland in Australia (Ingram, 2002). A significant decrease in dead material of plants after burning has also been observed by Blank et al. (1994) and Snyman (2003). The dead material of plants affects the structure of plant communities, and therefore could affect biomass production (Holm et al., 2002a, b). In most arid and semi-arid rangelands, dead material return is very slow (Whitford et al., 1988). The accumulation of dead plant material may also be affected by drought and windy conditions (Danckwerts & Aucamp, 1985).

S*accharum griffithii* Munro ex Boiss-ravennae (Linn.) Murr. hybrid is a low preferred species by small ruminants, and accumulates a great amount of material at the base of the plant. This material may in turn cause a negative impact on the development of meristematic tissues at crown level (Wright, 1985). After fire treatments to plants, if grazing is prevented, the removal of dead plant materials allows a higher production of new tillers (Pelaez et al., 2009). This is presumably due to a higher allocation of photo-assimilates to new tiller production than to supporting old structures (Briske & Richards,1994).

The rainfall varied in 2008 and 2009. Tomagh received higher rainfall in 2009 than in 2008. The response of burnt plants also varied between years. The number of tillers was lower in 2009 than in 2008 despite the greater rainfall during 2009. This response might be due to the cutting of the same plants in the second year. Our results showed that cutting of plants had a significant negative influence on growth and biomass production of the study plant species in this semi-arid region. Fire alone might have little impact on vegetation, but the interaction between fire and other ecological factors, such as herbivory and drought, has the potential to produce dramatic effects on plant growth (Whelan, 1995).

Burning caused substantial difference in crude protein contents of *S. griffithii*. Fiber contents were higher on unburnt than on burnt plots, whereas CP content was higher in plants of completely burnt plots. Unpalatable grasses avoid grazing because their relatively high contents of structural carbohydrates, particularly AUF, and the relatively low nutrient contents, particularly nitrogen (Moore & Jung, 2001). Despite the high content of fiber, *S. griffithii* is used by local farmers during the winter, months when other fodders are scarce. This study suggests that fire (controlled or prescribed) could be used as a management tool to increase the forage production and crude protein content of *S. griffithii* in the highlands of Balochistan.

Implications. Burning of *S. griffithii* decreased the accumulated above-ground dead plant tissues, increased forage production, increased protein contents and decreased AUF contents of above-ground plant tissues. Therefore, burning increased forage quantity and quality for ruminants in the Tomagh rangelands of Pakistan.

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