Nepalese Journal of Agricultural Sciences, January, 2024, Volume 26
eISSN 2091-0428; pISSN 2091-042X; esji ID = 6279

REVIEW ARTICLES

THE EFFECT OF GRAZING AND THE ASSOCIATED FACTORS ON THE NUTRITIVE VALUE OF HERBAGE IN RANGELANDS

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ABSTRACT

In rangelands, the relationship between plants and animals does not change in equilibrium vegetation conditions. However, the flora's composition is negatively impacted by the emergence of new biological processes and a noticeable decrease in plant growth vigor. The amount of grazing, one of the most crucial management factors, greatly affects the composition and structure of the grassland ecosystem. In non-grazed environments, highly palatable species typically predominate the herbage cover, while in grazed areas, non-palatable species prevail. When the herbage approaches the source of the grazing gradient, the concentrations of CP increase rapidly, while those of NDF and ME decrease rapidly. Animals can obtain certain elements from plants, which determines the nutritional value of feed. Variables such as light, temperature, and maturity all have a major impact on a plant's composition, albeit different types of plants differ in this regard. The edaphic and other biological factors have a considerable impact on the herbage's nutritional value. Early maturity is associated with a decline in CP content, while higher temperatures, more precipitation, and more biomass yield result in a faster allocation of biomass. The nutritional value of the herbage is determined by the regeneration of leaf portions after grazing causes the upper vegetation to become defoliated. This review focuses on the fundamental elements influencing the nutritional content of the herbage in rangelands, as grazing is a significant component in defining the quality of grasslands. The information is gathered using an available literature survey. The primary causes of the variables influencing the herbage's nutritional value in rangelands have been identified and compiled.

Keywords: Grazing, nutritive value, tillering, palatability, leaf: stem ratio

INTRODUCTION

Plants and animals constantly interact within the rangeland ecosystem (McNaughton, 1979). Due to increase in human and livestock populations puts overgrazing pressure in pasturelands and rangelands that causes a significant reduction in the vigour of plant growth, reproduction ability and poor growth and establishment of important valuable plant species which leads to changed botanical composition (Heitschmidt *et al*., 1987). The structure and composition of the grassland ecosystem are highly influenced by grazing intensity which is a key management variable (Hickman *et al*., 2004). Heavy grazing changes in vegetation composition from more palatable grasses and sedges to less palatable grasses and forbs have been reported in northwest China (Sun *et al.*, 2018). Grazing intensity affects the response of plant species richness. (Deng *et al*., 2014) reported that plant species richness decreases with increasing intensity of grazing in the grassland ecosystem. The author reported that at moderate and light grazing intensities observed the highest plant species richness. Spatial heterogeneity in light, soil nutrient availability and vegetation community dynamics is due to the random grazing pattern which can reduce plant competition with environmental resources because the vegetation exists in patches (Bakker *et al*., 2003). Moderate or light grazing intensity can promote the vegetation diversity within patch scale, but heavy grazing intensity can lead to a decrease in the palatable species (intolerant to grazing) and results in an increase in unpalatable species which are more tolerant to grazing (Watt & Gibson, 1988). The density of highly preferred palatable plant species for livestock grazing are decreased due to the over grazing pressure in rangeland(Warren *et al*., 1986).Species richness, diversity and forbs cover in tall grass prairie are significantly increased by grazing practices(Hickman *et al.*, 2004).Heavy grazing increased species richness and diversity but decreased forage quality and production in subalpine grassland in the eastern Pyrenees (Andorra)(Komac *et al*., 2014). Maintenance of grasslands is strongly dependent on the maintenance of biodiversity (Hartnett *et al*., 1996).The herbage cover in non-grazed site predominated mainly of high palatable species while non-palatable species predominated in the grazed site. The grass species are significantly higher in un-grazed sites as compared to a grazed site but forbs species were considerably decreased. The amount of litter was greater inside the un-grazed site and the more bare ground was identified in the grazed site (Amiri *et al*., 2008).

The current analysis generally clarifies that one of the factors influencing the botanical composition of the herbage, the abundance of palatable species, and the species richness in grasslands is the intensity of grazing.

Effect of grazing on nutritive values of forage

Grazing could influence the herbage nutritive value due to the use of young and protein-rich re-growth and to replace the older senescent parts of herbage (Albon & Langvatn, 1992).The CP concentration increases in re-growth of new tissues under grazing pressure and then maturation and lignification process of herbage species are delayed(Garcia *et al*., 2003). Furthermore, grazing could raise the nitrogen availability in the soil through animal excreta and increase the rate of N-mineralization in soil, which enhance the amount of CP in herbage (Shan *et al.*, 2011). The finding indicated that different herbage species have different strategies in adapting to grazing, including grazing avoidance (lower palatability) or grazing tolerance (greater re-growth ability) (Zheng *et al*., 2011). Nutritive value and yield of forage changes along with grazing gradient where sudden changes in vegetation composition of the community. At the grassland, rapid replacement of perennial grasses or forbs with weedy persistent annual forbs then the nutritive value of herbage could be changed. The CP concentration in herbage increased rapidly in approaching the source of the grazing gradient and whereas, NDF and ME concentration decreased rapidly(Sasaki *et al*., 2012). The quality of herbage was significantly higher in livestock grazed early in the season or continuously. Increased the herbage quality with increasing intensity of grazing as younger herbage and maintained re-growth was continued during the green season(Henkin *et al*., 2011). Different grazing intensities of cattle affects sward parameters such as diversity of plant species, the structure of sward, herbage growth and forage quality. The total biomass production was higher under the intensive grazing than the extensive grazing. Total crude protein (CP) contents and digestibility of forage were higher under intensive grazing. The crude fibre (CF) content showed a reverse effect (Pavlů *et al*., 2006). The nutritive value of forage plays a significant role in animal nutrition and management of grassland ecosystem in a sustainable manner and quality of forage is affected by grazing management. The concentration of crude protein (CP) in the plot of heavy grazing pressure through all season and heavy grazing in spring and summer and moderate grazing in autumn were higher than rest grazing in spring, moderate grazing in summer and heavy grazing in autumn and rest grazing in spring, heavy grazing in summer and moderate grazing in autumn. The nutritive value of *L. chinensis*was more responsive to grazing disturbance than *Artemisia* spp. And*C. duriuscula*, and heavy grazing maintained a relatively high crude protein content in all species(Zhai *et al*., 2018). The use of complex mixture (more than three species) of herbage may increase the production of pasture and the productivity of mixture is affected by the management of grazing. When the sward reached 25 cm in height (SH) produced 30% more dry matter (DM) than the alfalfa reached a bud stage (MP). The SH stage produced herbage of better nutritive value than MP stage at first harvesting of the year because they produce more crude protein (CP), in vitro true dry matter digestibility (IVTDMD) and less acid detergent fibre (ADF) and neutral detergent fibre (NDF). More consistency in yield of DM in a complex mixture of forage species than binary legume-grass mixture or grass monoculture in variable environments(Deak *et al*., 2009). The clipping frequencies affect the cumulative yield of herbage. The canopies clipped at 6-week intervals produced more herbage than those clipped at 3-week intervals. Fluctuations in the in vitro organic matter disappearance (IVOMD) and crude protein (CP) were related to changes in sward composition arising from the interaction of time and clipping frequency. The greater the CP concentration when sward clipped at 3-week intervals than those clipped at 6-week intervals.Canopies clipped at 3-wk intervals hadrelatively constant NDF over the growing season,but those clipped at 6-wk intervals increased in NDFas the growing season progressed (Belesky *et al*., 1999). Key herbage species had significantly higher in vitro organic matter digestibility (IVOMD) and crude protein (CP) content in rainy season than in dry season but neutral detergent fibre (NDF) and acid detergent fibre (ADF) did not vary significantly with the season. The above-ground biomass of herbage was significantly higher in the rainy season than the dry season. Cattle spent considerably more time for grazing and goat for browsing in the rainy season than the dry season(Selemani *et al*., 2013). The availability of nutrients in the plat for animal determines the nutritive value of forage. This availability is controlled by the chemical composition of the forage in respect to factors limiting the utilization of cellulose and hemi-cellulose. These include lignin, silica, and the total amount of plant cell wall substances. An important part of nutritive value is that of consumption or voluntary intake which is partly related to cell wall content and bulkiness of the forage. The composition of the plant is controlled to a large extent by light, temperature, and maturity factors, but different plant species vary individually in this respect(Van Soest, 1969).

Overall, the literature that is currently available indicates that grazing modifies the nutritional value by raising the concentration of crude protein and the digestibility of the growing shoots; however, additional edaphic and biological processes may also be at play. It is also assumed that the species that can withstand grazing may continue to exist with a higher fiber content.

Effect of environmental factor on the nutritive value of herbage

More precipitation in a year correspondingly increase the soil water availability and thus promote biomass production of herbage, which might induce the dilution of CP in the herbage biomass (Grant *et al*., 2014). Higher the concentration of CP in herbage biomass in wetter year due to increased availability of nitrogen to the plants because of accelerated N-mineralization(Austin et al., *2004*),and higher capacity to herbage to assimilate nitrogen (Xu and Zhou, 2006). Meanwhile, drought condition could cause severe water stress to herbage resulting in rapid plant maturation and thus decrease N-concentration in herbage(Schiborra *et al*., 2009;Wang *et al*., 2011). Nutritive value of forage was decreased at higher temperature and changes the identity of species and changes to phenology and physiology. Where raised temperatures reduce the nutritive value of grass and similarly may increase methane production by 0.9% with 1^0 C temperature rise. Increase the concentration of neutral detergent fibre (NDF) by 0.4% every 1^0C rise in temperature during the sampling period. NDF was affected by the photosynthetic pathway, with the NDF content of C_4 species than C_3 species. These C_4grasses were commonly founded at warmer sites, so NDF content was greater in tropical herbage. They pointed out that the cultivation of nutritious rich forage plants and reduced animal farming in a warmer region may reduce the pastoral greenhouse gas emission(Lee *et al*., 2017). The influence of environmental factors like light, temperature, drought, soil nutrients influence on forage quality (chemical composition and digestibility) of temperate and tropical grasses. Change in climatic and edaphic factors influence the quality of legume forage with variable levels of condensed tannins, which is an important secondary compound of some tropical and temperate legume species. Properties of tannin and their positive and negative effect influenced on forage quality of legumes. The accumulations of condensed tannin in temperate and tropical legumes were affected by temperature, drought, CO_2concentration, the season of the year and soil fertility. The result founded that higher temperature alone can significantly increase the accumulation of condensed tannin in some temperate legume forage species but not all species. High nutritive value of herbage is characterized by the high concentration of crude protein (CP), high concentration of cellulose digestible organic matter (CDOM), and low concentration of neutral detergent fibre (NDF). For all herbage species, nutritive value is higher in the wetter year than drier year and highest in the early growing season (June) and lowest at the end of the growing season (September). Inter-seasonal and inter-annual variations in nutritive value were much higher for *L. chinensis* and *A. michnoi*than for *C. squarrosa* and *S. grandis*, suggesting higher water use efficiency for the latter two species. Grazing significantly decreased the drought resistance of three herbage species, but not of *S. grandis* (Ren *et al*., 2016).

In conclusion, the review of the literature on the impact of environmental conditions, such as temperature and precipitation, on the nutritional content of herbage indicates that these variables are what determine the nutritive value. Nonetheless, physiological characteristics of the plant, such as C3 and C4, may also influence the nutritional value.

Effects of sampling season on herbage nutritive value

Sampling season affects the nutritive value of herbage(Wang *et al*., 2011). The growing period progressed, herbage cellulose digestible organic matter (CDOM) and crude protein (CP) decreased, while neutral detergent fibre (NDF) increased. The finding indicated that herbage nutritive value reduced as the vegetative period progressed (Ren *et al*., 2016). When plants stop growing, the maturation and lignification process begins cell wall content such as cellulose, hemicellulose and lignin increases while cell substances such as crude protein decrease (McNaughton, 1983). Low responses of nutritive value to grazing in September would also come with reduce plant cover and high risk of wind erosion because sheep need to increase feed intake to meet increased energy requirements from grazing (Glindemann *et al*., 2009). Higher herbage intake in September would also reduce the remaining biomass and energy to be stored in plant stem bases, roots and rhizomes, which are important for the maintenance of plant growth (Johnson &Tieszen, 1976) in next year(Pérez-Harguindeguy *et al*. 2013). High grazing intensity may negatively affect grassland productivity in the long term through the 'carry-over effect'. Supplementary feeding is required at the end of the vegetation period to maintain livestock production in intensely grazed grasslands and to protect the grassland ecosystem (Müller *et al*. 2014).

In summary, the plant maturity factor can affect the nutritive value of herbage; as a plant ages, the distribution of fibrous residues causes the nutritive value to decrease.

Effect of grazing on tillering and leaf: stem ratio of forage

Leaf/stem ratio is an important factor that determines the quality, diet selection, and forage intake (Forbes & Coleman, 1993).The grasses are more tolerant to grazing and defoliation as compared to other herbage species. They have characteristics of sequential leaf production and un-accessible apical meristems in arctic and subarctic environments (Johnson & Tieszen, 1976)comparatively high level of carbohydrate reserve and possession of clonal growth with physiologically integrated tillers (Archer and Tieszen 1986). Repeated defoliation due to continuous heavy grazing may affect biomass partitioning of a tiller and their population dynamics. If the tiller is repeatedly defoliated, support from physiologically integrated neighboring tillers is cut off(Jónsdóttir *et al*., 1989). The energy level and nutrient reserve are decreased, which can reduce the production of biomass, the survival of tiller and rate of flowering(Mattheis & Tieszen, n.d.).The defoliation effect in graminoids tillering depends on the number of available resources and whether the apical meristem is damaged or not (Jameson, 1964). The moss was not grazed by livestock but more sensitive to trampling. The dry weight of moss was four times greater in un-grazed sites as compared to grazed sites (Jónsdóttir & Jonsdottir, 1991).

In fact, the defoliation by gazing alters the leaf: stem proportions due to sparing of nutrient reserves for the growth of young tillers and leaves respectively. The leaf: stem ratio further determines the intake and preference by grazing livestock. There is much accumulation of NSC than the fibres, however it depends on season and herbage species, net photosynthesis and time of defoliation etc.

Nonstructural Carbohydrate Accumulation

The carbohydrates are classified as structural and nonstructural forms. The polysaccharides such as pectin, glycogen, cellulose and hemicellulose are structural carbohydrates because they are a component of the cell wall and provide structural support to the herbage plants (Raven *et al*., 2005). Nonstructural carbohydrates assists in energy transport and energy storage and intermediary metabolism in the plant(Moore & Hatfield, 1994). Intermediary metabolism involves the pathways that synthesize, degrade, and transform important metabolites as well as conserve energy. A nonstructural carbohydrate indicates the simple sugars (glucose, fructose, and sucrose), fructan, and starch. Total nonstructural carbohydrates (TNC) is a term used to describe these carbohydrates, which is commonly used as an indicator of herbage quality(Jensen *et al*., 2014).The accumulation of nonstructural carbohydrates in herbage occurs when carbohydrate production from photosynthesis is greater than the amount required for herbage growth and development (Watts & Chatterton, 2004). Excess carbohydrates produced from photosynthesis process are substituted as reserve carbohydrates, which are deposited during the day time and some portion are loosed at night by respiration to produce energy for growth and maintenance(Preiss & Levi, 1980).The combination of these processes results in a daily cycle that usually causes nonstructural carbohydrate concentrations to be highest in the afternoon and lowest in the morning. Fructan is reserve carbohydrate for vegetative tissues and starch serves as a reserve carbohydrate for seeds of cool-season grasses. Fructan is stored in stem vacuole which is translocated from leaf vacuole, therefore cool-season herbage commonly accumulates the high amount of fructan in stem base or lower stem (Longland & Byrd, 2006).The herbage accumulates the carbohydrate in different parts. The sucrose stored higher concentration (8.9% on a dry weight basis) in the root and upper two-third of leaf blades and fructan stored higher concentration (36.2% on a dry weight basis) in the lower half of debris (Sprague and Sullivan, 1950).The grasses and legumes during warm-season commonly produce less amount of total nonstructural carbohydrate than cool-season grasses and legumes, because they do not produce fructan. Warm-season legumes and grasses use starch instead of fructan as their chief reserve of carbohydrate (Chatterton *et al*., 1989).Animal preference is highest in afternoon cut hay as compared to morning cut hay related with raised total nonstructural carbohydrate (TNC) and in vitro true dry matter disappearance, and reduced neutral detergent fibre (NDF) (Fisher *et al*., 1999). The concentration of nonstructural carbohydrate in forage is seasonal variation. (Pollock & Jones, 1979) documented fructan metabolism monthly in the cool-season grasses meadow fescue (*Festucapratensis* L.), timothy (*Phleumpratense* L.), and perennial ryegrass (*Loliumperenne* L.). They found that, fructan stored was highest in fall and winter, with maximal amount documented in December, when growth was restricted but photosynthesis continued. The highest concentrations of nonstructural carbohydrates of tall fescue and Kentucky bluegrass (Poapratensis L.)founded in the spring and fall months (Cubitt *et al*., 2007). Both pasture and hay samples followed seasonal trends in spring, with maximum levels in early-April and minimum in May and June(Kagan *et al*., 2011). This trend indicated that seasonal variations in nonstructural carbohydrate concentration are correlated with the growth stage of the plant. Less amount of nonstructural carbohydrate is accumulated during a rapidly growing stage (i.e. young stage) because the energy required producing new growth. Therefore, with a season and maturity stage of plant will greatly affect the concentration of nonstructural carbohydrate. Environmental factors such as photo-synthetically active radiation (PAR), precipitation and temperature can affect the production and utilization of nonstructural carbohydrate. (Chatterton *et al*., 1989) demonstrated that, while cooler temperatures (5-10^{o} C) have been associated with maximum carbohydrate concentrations, warmer temperatures (15-25^{o}C) have been associated with minimum carbohydrate concentrations. The carbohydrates either reduced or remained at low concentrations under rainfall and temperature conditions that promoted grass growth. (Waite & Boyd, 1953) identified low concentrations of fructan during periods of growth after rising temperatures due to utilization of carbohydrate reserves. The photosynthetically active radiation

(PAR) has a significant influence on the concentration of nonstructural carbohydrate. Low PAR generally results in reduced nonstructural carbohydrate concentrations and high PAR commonly results in higher nonstructural carbohydrate accumulation.(Ciavarella *et al*., 2000) documented that lower the concentrations of nonstructural carbohydrate of forage in shaded areas as compared to forage grown to open non-shaded areas.

Effect of grazing on herbage productivity of grasslands

The role of herbivores in controlling plant species richness is a critical issue in the conservation and management of grassland biodiversity. The herbivores often, but not always, increase plant diversity (Olff & Ritchie,1998). Ward (2006) documented that the higher coverage of perennial, erect, tall species with longer growing season were observed in the protected grasslands and grazing increased mostly small, prostrate, rosette plants. The identification of easily measured plant functional traits that consistently predict grazing response in a wide spectrum of rangelands would be a major advance. Plant height was the best single predictor of grazing response, followed by leaf mass. The best prediction of species to grazing response was achieved by combining plant height, life history and leaf mass. Specific leaf area (SLA) was a comparatively poor predictor of grazing response (Diaz et al., 2001).

The potential benefits of herbivore to plants have been debated over the last decade. Several investigators claim that removal of or damage to the productive, absorptive, or reproductive tissue of plants by herbivores benefits some plant species by increasing their net primary productivity, seed production, or longevity, and that these changes increase plant fitness and result in the evolution of herbivore-plant mutualisms (Belsky, 1986).Grazing can alter the spatial heterogeneity of vegetation, influencing ecosystem processes and biodiversity (Adler et al., 2001).Most soils under grazed pasture, compaction to greater depth, and other changes in soil physical properties, are more likely in recently tilled or wet soils (Greenwood & McKenzie, 2001). Pastoral fallowing over a growing season (October–May) has a profound effect on standing biomass and sward structure, and should have an impact on below ground plant growth and soil biological activities (Nie *et al*., 1997).

Stocking rate and grazing disturbances

The grazing disturbs plant species composition in permanent grasslands (Hickman et al. 2004). Increased stocking rate stimulates the functional properties such as increase in ruderal and competitive species (Grime *et al*., 1988); early flowering and seed dispersal, rosette habit, and lower minimum height (Pakeman, 2004). Conversely, low-stocking rate favors stress-tolerant grasses (Grime *et al*., 1988) and forbs but depending on the starting floristic composition and site conditions (Dumont *et al*., 2009). In a sheep grazed pasture, the richness of dicot species found increased with increasing stocking rate (Bullock *et al*., 2001), however, the intensity of grazing might govern such results. Stocking rate can influence the plant diversity of permanent grasslands through two mechanisms: removal of vegetation and trampling (Gaujour *et al*., 2012). Grazing by herbivores leads to spatial heterogeneity of the plant canopy (Wallace, 1987), light penetration to lower canopy (Rook & Tallowin, 2003), and in such situations the creeping vines could grow faster (Pavlu *et al.,* 2007). Trampling induces gap in the pasture and larger ruminants are better species as compared to others (Stoneburner *et al*., 2021). Thus, maintained gaps could be the source for seedling recruitment and species diversity (Lavorel *et al*., 1994). Stocking rate dramatically influences botanical composition of grasslands, working on the recruitment, survival, and dispersion of species (Gaujour *et al*., 2012).

CONCLUSION

All things considered; it is possible to conclude that grazing disturbance may change the grassland niches. Because too much aboveground biomass is removed, the floristic composition would decrease and heterogeneity would primarily rise as the stoking rate increased. The level of herbage defoliation and trampling in the grazed pastures would be interesting areas of rangelands research in the rears to come.

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