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Review Article

REVIEW ON BIOMASS YIELD DYNAMICS AND NUTRITIONAL QUALITY OF ALFALFA (*MEDICAGO SATIVA)*

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Abstract: Ethiopia endowed large number of livestock population despite less profit from the sector because of poor nutrition among others factors. In Ethiopia the common feed sources for livestock particularly beef and dairy cattle is natural pasture and crop residue, which is poor in quality unless supplemented by cultivated legumes like alfalfa. Most of legume forages are a protein source in livestock nutrition and of which, those homegrown feeds make farmers less dependent from the purchase of other protein source. Alfalfa is one of the most important forage crops worldwide due to its high forage quality, yield, and adaptability to different climatic conditions. There are numerous cultivars of alfalfa, selected for specific abilities, such as winter hardiness, drought resistance, tolerance to heavy grazing or tolerance to pests and diseases. Growth stage, cut number, leaf to stem ratio, moisture conditions at harvest and processing method are the most important causes of variation for yield of alfalfa. Decreasing protein content is a dilution effect related with the decreasing leaf to stem ratio; the leaves have stable protein content and their protein level is much higher than the protein content in stems. Cultivars and their genetic characteristics crucially determine the volume and stability of yield, as well as the quality of alfalfa forage. With increasing maturity, plant structural carbohydrates, as measured by the ADF and NDF fractions, increase. These fiber fractions represent the more indigestible parts of the plant. As a result, digestibility and energy obtained through fermentation decrease with maturity. Relative feed value (RFV) has been used for years to compare the quality of legume and legume/grass hays and silages.
Abbreviation: ADF= Acid detergent fiber, NDF= Neutral detergent fiber, RFV= Relative feed value

Key words: Alfalfa, Leaf and stem yield, chemical composition

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Introduction:

Livestock play a crucial role in Ethiopian agriculture. Currently, productivity per animal is very low, and the contribution of the sector to the overall economy is much lower than expected due, among others, to poor nutrition. The larger proportion of livestock feed comes from natural pastures and crop residues that are deficient in important nutrients like protein and energy (Tessema and Barras, 2006). Most of legume forages are a protein source in livestock nutrition and of which, those home grown feeds make farmers less dependent from the purchase of other protein source. This is an advantage for the farm economy and ecology, particularly because of restrictions concerning the environment since the prohibition of the use of animal protein in livestock nutrition. Moreover, the capacity of legumes to fix nitrogen from the air results in high protein contents, particularly in alfalfa (Gosselink, 2004).

Alfalfa is one of the most important forage crops worldwide due to its high forage quality and yield and adaptability to different climatic conditions (Turan *et al*., 2009). It can be used directly for grazing or conserved as silage or hay and is a reliable forage species that could represent a significant contribution to the livestock sector (Borreani and Tabacco, 2006). As a perennial legume, alfalfa may be used as a cover crop; its roots improve soil texture and its leaves add organic matter and nitrogen to the soil. The herbage DM yield and chemical composition of alfalfa depends on cutting cycles and cultivars, among others. Crude protein tends to be lower in aged alfalfa plants while the content of crude fibres increases (Stanaćev *et al*., 2008).

The intension in alfalfa forage production is on improving fodder yield and quality. This can be improved by increasing the leaf/stem ratio, which could be achieved by selecting genotypes (Cultivars) with having high leaf to stem ratio. On the other hand, to facilitate multiplication of the new cultivars, it is necessary to combine high fodder yield and quality (Bolanos *et al*., 2002). It has a high quality potential and ability to control factors that can affect the quality and will improve production quality. Factors affecting alfalfa hay quality are: soil fertility, cultivar, the presence of other species, the use of pesticides, climatic conditions, harvesting (season, time of day and stage of development at harvest) and the method of preservation (Stancheva *et al*., 2008).

Evaluation of nutritional status is an important part of experimental assessment since inadequate nutrition increases the risk of health and performance problems (Becvarova *et al*., 2009). Nutritive value of alfalfa forages depends on their DM digestibility and voluntary DM intake. Relative feed value (RFV) is a widely accepted forage quality index in the marketing of hays. It combines the estimates for forage digestibility and intake into a single number. RFV value is calculated from estimation of acid detergent fiber (ADF) and neutral detergent fiber (NDF) (Caddel, 2005). Hay producers and purchasers also use RFV in price discovery, especially in hay auctions (Undersander, 2001). The amount of protective substances residue obtained after boiling the sample feed with detergent solution is called ADF. ADF content is regularly higher than the crude fiber from forage, these features being closely related, since both are an estimate of the amount of cellulose and lignin (Jarrige *et al*., 1988).

The estimated livestock population of Ethiopia is 38.7 million cattle, 16.1 million sheep, 14.9 million goats, 5.8 million equine and 0.46 million camels (CSA, 2005), despite their productivity is low. Among other limiting factors, poor feed supply and feeding system is the most important as the feed resources in the highlands of Ethiopia are generally natural pasture and residues of different crops (Zegeye, 2003). McDonald *et al.* (2002) stated that all straws and related by-products are extremely fibrous, most of them have a high content of lignin and all are of low nutritive value. In connection to this, most dry forages and roughages found in Ethiopia have a crude protein (CP) content of less than 7% which indicates microbial requirement can hardly be satisfied unless supplemented with protein rich feeds (Van Soest *et al*., 1994).

Therefore to improve availability of livestock feed in terms of quality and quantity it is better to cultivate alfalfa forage that have better biomass yield and nutritional quality. Thus, this paper aimed to review the biomass yield dynamics and nutritional quality of alfalfa (*medicago sativa*) cultivars.

Literature Review

Overview of livestock Feed Resource in Ethiopia: The major feed resources in the country are crop residues and natural pasture, with agro industrial by-products and manufactured feed contributing much less. The importance of natural pasture is gradually declining because of the expansion of crop production into grazing lands, redistribution of common lands to the landless and land degradation. In the Ethiopian highlands crop residues are the major feed resources (Berhanu *et al.*, 2009). Zinash and Seyoum (1991) reported that about 70% of crop residues in the highlands are used as animal feed. In the lowlands of the country natural pasture is the major source of feed. EARO (2003) reported that there are no reliable estimates of the animal feed resources in Ethiopia. Also the author indicated, some estimates reported that there could be about 14 million tonne of crop residues and about 500,000 tonne of various types of agro industrial by-products produced annually in Ethiopia.

Despite the large livestock population in Ethiopia, the sector's contribution at the micro or the macro level is well below its potential due to various reasons, notably feed shortage and diseases (Gebremedhin *et al*., 2004). This author also indicated, introducing improved forage species, and cut and carry systems are other potential options that could contribute to the alleviation of the feed shortage problem, especially in the highlands of the country.

Forage legumes contribute significantly to livestock production in crop livestock systems. Low quality crop residues need nitrogen supplementation, often provided by forage legumes to become productive diets (Anderson, 1985). Legume forages generally lead to higher intakes and animal production than grass silages of comparable digestibility (Dewhurst *et al.*, 2003). In livestock production one of the most important factors determining profitability is to achieve optimal level of feeding. Livestock farming communities are facing their biggest challenge during the dry season.

Producing supplementary feed on farm by establishing grass/legume pastures would reduce their problem. For instance mixed grass legume pasture produced higher DM yields of better nutritive value than sole grass swards (Oni-fade and Akinola, 1986).

According to (Alemayehu, 2006) finding, alfalfa Forage plays varying role in different livestock production systems. Even in the presence of abundant crop residues, which are often free fed to ruminants, forage crops especially legumes are needed to improve the utilization of crop residues, crop residues often provide energy while forage legumes provide proteins.

History of Alfalfa: Alfalfa yield and the nutritive value of dry matter make it a leading perennial leguminous forage crop (Dinić and Đorđević, 2005). It originated from the Mediterranean basin and southwest Asia (Iran, Afghanistan) and was one of the first forage crops to be domesticated (Cook *et al*., 2005). However, the evolution of cultivated alfalfa, *Medicago sativa* ssp., has been greatly influenced by its winter hardy progenitor (Michaud *et al.,* 1988). It has a deep root that reaches down to 4 m, but can reach 7-9 m in well drained soils and stems are erect or decumbent, up to 1 m high, glabrous or hairy in the upper parts. Leaves are trifoliate, with obovate leaflets, 10-45 mm long and 3-10 mm broad (Ecoport, 2009). Aalfalfa is one of the few cultivated plants that can produce high level of biomass with minimum inputs. Sustainability of farming system under organic management may be increase by the introduction of alfalfa in the crop rotation *(*Annicchiarico *et al., 2006).*

There are numerous cultivars of alfalfa, selected for specific abilities, such as winter hardiness, drought resistance, tolerance to heavy grazing or tolerance to pests and diseases (Frame, 2005). Current breeding targets also include feeding value parameters such as digestibility and fiber content (Julier *et al.*, 2000). Due to its high nutritional quality, high yields and high adaptability, it is one of the most important legume forages of the world as major source of protein for livestock and it is a basic component in rations for dairy cattle, beef cattle, horses, sheep, goats and other classes of domestic animals.

Alfalfa as a Feed for Animals : Alfalfa is used for livestock nutrition in different forms, most frequently as hay, but also dried/dehydrated in form of briquettes, as silage, haylage or for grazing. Alfalfa is harvested and stored primarily as hay or silage for use on the farm. The feeding value of harvested alfalfa may be changed by post-harvested factors as much as by precutting environment and history of plant (genetics). According to Radović *et al*. (2009) report, Conservation and storage system are designed to minimize the loss and deterioration of nutrients.

Alfalfa is widely used in ruminant livestock diets, impacting the performance of beef and dairy animals as well as the cost of production. The decline in forage nutritive value with increasing harvest interval is a consequence of progressing maturity, along with the associated effects of increasing stem growth and decreasing leaf proportion, and decreasing stem nutritive value. The implications of greater maturity for animal performance are generally negative (Brink *et al*., 2011).

It is a highly valued animal feed and a rich source of proteins, fibers, minerals and vitamins used in the diet of livestock. Alfalfa does not tolerate close grazing well, and some form of rotational grazing is necessary to maintain the persistence and production of plants, with rest intervals that replenish the crown and roots of plants in carbohydrates and nitrogen (Frame, 2005).

Ruminants fed on alfalfa have higher nutrient intake and digestibility than when fed on other forage legumes and grasses (Frame, 2005). It may supply more than 30 % of the total digestible nutrients supplied by the same quantity of maize grain (Bruce *et al*., 2008). The value of high-quality alfalfa for dairy cows is that it reduces grain and protein needs by providing variable protein content and solubility, as well as relatively high energy. The ability of alfalfa to provide approximately 25% more high quality feed than pasture, results in higher production potential. This is significant in economic terms (Moot, 2009).

Biomass Yield of Alfalfa: Alfalfa is one of the highest yielding forage legumes. Under irrigation, it can produce 25 to 27 t/ha DM with a production reduced in the 3rd year to 8-15 t/ha DM. Production may be related to plant density, to disease resistance, cutting cycle and cultivar difference. Under rain-grown situations the production is also determined by the availability of soil moisture (Cook *et al*., 2005). There is a negative association between yield and nutritive value, which has greatest impact on timing of harvests made in spring and early summer in humid environments, and in early and late summer in more arid regions (Brink *et al*., 2010).

Best quality hay is obtained when cutting is done during a dry period so that the swathe dries quickly. Raking has to be done at 60 % DM, as carefully as possible so that the plant does not lose its leaves. Baling should be done at 82 % DM. These conditions are generally satisfied in small-scale farms (Suttie, 2000). Dehydration was found to be the best way as it dries and stabilizes alfalfa while preserving its high protein content, vitamins and overall nutritive value (Rwnaud, 2002). Moreover, dehydrated alfalfa is a good source of xanthophylls and beta-carotenes for poultry farmers (Coop de, 2008).

The high dry matter yield, protein and calcium content of alfalfa make it suitable forage for all classes of ruminants. Alfalfa can be grazed, fed as green forage, offered as hay and silage or dehydrated. Cattle highly relish it though there are palatability differences among cultivars that could result from different patterns of protein fractionation (Summers *and* Putnam, 2008).

Generally speaking, alfalfa forage quality declines as the summer progresses and tends to recover under autumn conditions. Alfalfa harvested in the spring or fall has a higher leaf and protein content than summer produced alfalfa, at the same maturity, due to the effects of temperature and photoperiod. High temperature, which increases the rate of plant maturation and cell wall lignification, has a dominant effect. Therefore, the rate of decline in digestibility with time is faster in summer when temperatures are higher than in spring or autumn when temperatures are low. Structural components rapidly form at the expense of metabolites in the cell contents when temperatures are high. This affects the quality of the forage because lignification of the cell wall is the primary factor limiting forage digestibility.

Effect of cultivar and cutting cycle on biomass yield of alfalfa: Growth stage, cut number, leaf to stem ratio, moisture conditions at harvest and processing method are the most important causes of variation for yield of alfalfa (Veronesi *et al*., 2010). Before flowering, alfalfa's nutrient uptake has been to promote vegetative growth. After flowering, nutrient absorption and photosynthates are diverted into seed production. This allows for the alfalfa yield to keep increasing, but quality decreases rapidly past this stage of development (Probst, 2008). The optimal harvest interval for alfalfa is between 30 to 35 days. However, this harvest interval is also based upon a compromise between yield, quality, regrowth, and persistence (Sheaffer, 2000). Maximum yield on alfalfa is achieved at reproductive maturity when the nutritive value of the forage is at a minimum (Collins and Fritz, 2003).

Its leaves and stems contain different crude protein and crude fibre concentrations at different stages of growth. Herbage harvested at full bloom is expected to have a higher stem proportion than less mature herbage. The proportion of leaves in it's at the time of harvest is a major factor that determines the quality of the forage (Jung, 2005). The leaves/stems ratio varied depending on the number of cuts and harvest cycles and the leaves/stems ratio is an important quality indicator, because of this depend quality of alfalfa hay obtained. Percentage of leaves is desirable to be as high as possible, because in the leaves are found a crude protein content better than stem (Mihai *et al.*, 2012). Leaf to stem ratio higher than 1.8 was under estimated, but within the range of 0.5-1.8 prediction was accurate according to the report of (Julier, 1997).

Nutritive Value of Alfalfa: There are a number of chemical components of alfalfa hay that can be determined by currently available laboratory techniques. These allow the alfalfa hay to be divided into its ash (i.e., mineral) component (9 to 13% of hay dry matter (DM)), fat (2 to 3% of DM), protein (15 to 25% of DM), non-structural carbohydrate such as sugars, pectin and starches (20 to 35% of DM), and structural carbohydrates (30 to 50% of DM). Ash, protein, fat and structural carbohydrate (usually defined as fiber insoluble in a solution of boiling detergent at a neutral pH, or neutral detergent fiber (NDF)), are generally assayed directly, while the level of non-structural carbohydrate (NSC) is calculated by difference. Energetically, ash has no value while fat; NSC and proteins are generally almost fully digestible somewhere in the digestive tract. Thus the energy value of the hay, exclusive of the NDF, can be calculated with some accuracy. However it is the NDF portion of the hay, due to its relatively high contribution to the overall weight of the hay and its variable digestibility that makes it a key variable in estimating the energy value of alfalfa hay (Robinson, 1999).

Protein content in alfalfa dry matter varies from 18 to 25% depending on the growth stage (cutting cycle), cultivar difference and other factors. Alfalfa nutritive value is identified with protein content which depends on the share of leaves in dry matter yield which in its turn is positively correlated with protein content. The proportion of leaves and stems in alfalfa hay can vary greatly, depending on maturity at harvest, cultivars, handling, and rain damage (Katic *et al.*, 2006). The nutritive value of alfalfa may also be improved by increasing its DM digestibility. Digestibility of alfalfa decreases with maturity as a result of increased concentration of cell wall material in stems, decreased stem digestibility, and decreased leaf weight ratio (LWR) (Albrecht *et al*., 1987).

Decreasing protein content is a dilution effect related with the decreasing leaf to stem ratio; the leaves have stable protein content and their protein level is much higher than the protein content in stems. The decline of digestibility is the consequence of two processes: (a) the reduction of the highly digestible component (leaves) because of an increase of the less digestible component (stems) and (b) the decreasing average digestibility of the stem component, with more cell walls (NDF) and lignin *(*Veronesi *et al., 2010).*

When determining the nutritive value of alfalfa, ligneous cellulose content should be taken in account in addition to crude protein content. Neutral detergent fiber (NDF) content indicates the intake rate of alfalfa dry matter. The higher the NDF, the lower the alfalfa quality - the content of nutrients is reduced and livestock consumes such alfalfa less readily. In consequence, the livestock grows at a slower rate and the production of livestock products is proportionally reduced. ADF content indicates the potential production energy. Increase in ADF indicates a reduced energy, i.e., reduced quality (Katić *et al.,* 2008).

Digestibility of alfalfa organic matter depends on the contents of cellulose and lignin. As lignin is virtually indigestible, intensive lignifications of cell wall in late stages of alfalfa development tends to reduce the coefficient of digestibility. Since alfalfa leaf is preferably eaten by animals and has better nutritive value than stems, appropriate stage of maturity and cultivars having high leaf yield is important for livestock feed (Anacleto, 2004). Alfalfa has the potential to produce quality forage that is high in protein and carotene but low in fiber. Growing alfalfa is easy, but to produce a high yield of good quality forage and still maintain the stand demands attention to sound management practices namely: variety selection, insect and weed control, soil fertility and cutting management (James *et al*., 1984).

There is an optimum quality for alfalfa that should be fed to dairy cows. For forage that serves as the primary fibre source in the diet, NDF is the principal forage quality variable of concern. NDF is defined as the remnants of a feedstuff that is retained offer dissolving in a neutral detergent; consisting of cellulose, hemicellulose and lignin. Cellulose and hemicellulose are wall carbohydrates and are available for degradation by rumen microbes, which in turn produce volatile fatty acids. Lignin is anti-nutritive phenolic compound that is indigestible by rumen microbes. The ideal NDF level in alfalfa hay for dairy cows is 40 % (of dry matter). NDF levels below 40% are to low and the hay have high rates of passage through the rumen; resulting inefficient dry matter conversion. NDF levels greater than 40 % begin to slow rate of passage down, creating a gut-fill effect. Higher gut-fill results in lower dry matter intake; and dry matter intake drives milk production (Găvan *et al*., 2013).

For forage trading (i.e., buying or selling), one number to describe different hays is more convenient rather than comparing their full nutrient analyses profiles. Such a Relative Feed Value (RFV) has been in place and proven very useful for livestock producers and hay farmers for long time to price hay and predict animal performance. Full bloom alfalfa hay containing 41% ADF and 53% NDF on a dry matter basis has an RFV of 100 and is considered the average score. Forages with RFV greater than 100 are of higher quality than full bloom alfalfa hay, and forages with a value lower than 100 are of lower value than full bloom alfalfa (Moore and Undersander, 2002a, 2002b).

Digestibility is one of the most important characteristics of forage nutritional value. Differences among cultivars for IVOMD (in vitro organic matter digestibility) of stems were highly significant in both spring growth and summer regrowth. In spring, the stem IVOMD ranged from 547 to 579 g /kgDM, while in summer, it ranged from 536 to 563 g /kg DM. Differences in stem digestibility among alfalfa populations, cultivars, plant introduction accessions, and phenotypes have been reported (Tremblay, 2001).

Lignin levels increase with maturity in stems of forage crops such as alfalfa. Lignin concentration correlates negatively with forage digestibility for ruminant and small decreases in lignin content can improve digestibility and therefore profitability for the farmer or rancher (Dianging *et al*., 2001).

Roles of cultivar and cutting cycle for alfalfa nutritive value: The main effect on alfalfa forage quality belongs to plant stage (maturity). Differences between alfalfa cultivars are not significant *(*Julier *et al., 2000;* Radović *et al., 2004).* The decline in alfalfa forage quality with advancing maturity is well documented *(*Marković *et al., 2008).* This decline in quality is associated primarily with a decrease of crude protein content and to an increase in fibrous constituents of the steam. Digestibility and crude protein content of stem declined at a faster rate than those of leaves with increased maturity.

Organic matter digestibility ranges from 55 % to 77 % and depends on growth stage, cut number (leaf: stem ratio), and cutting frequency, harvesting conditions and processing (INRA, 2007). Factors affecting quality are represented by soil fertility, cultivar, the presence of other species in culture, the use of pesticides, climatic conditions, harvesting (season, time of day and stage of development at harvest) and the method of preservation (Stancheva *et al*., 2008). Advancing plant maturity is associated with a lowering of nutritive value by virtue of a decrease in leafiness and an increase in the stem: leaf ratio, change in the composition of the cell wall and loss of cell contents with maturity (Ballard *et al*., 1990).

Many factors affect the nutritive value of alfalfa hay: Variety selection, Harvest management, Harvest frequency. Cutting at earlier stages improves crude protein content and decreases fiber formation, but at the expense of yield (Dennis and Howard, 1993). Temperature and light are probably the most important environmental factors that affect nutritive value, both directly and indirectly. Higher temperature usually promote the accumulation of structural material (i.e. cell wall material) and also more rapid metabolic activity which decrease pool size of cell contents (Ford *et al*., 1979).

Table 1 Forage quality values of some forages at different growth stages.

Forage type	*CP*	*ADF*	*NDF*	*RFV*
Alfalfa-prebud	22	28	38	164
Alfalfa-bud	20	30	40	152
Alfalfa-early bloom	18	33	43	138
Alfalfa-full bloom	16	41	53	100
Alfalfa + grass	13	39	54	101
Bromegrass,				
Bromegrass-late bloom	7	49	81	58
Corn silage-well eared	10	28	48	133
Sorghum silage	8	32	52	114

Source: (Dunham 1998 and INR, 2007)

Cultivars and their genetic characteristics crucially determine the volume and stability of yield, as well as the quality of alfalfa forage (Stanisavljević, 2006). Significant differences were registered in the contents of crude fiber, ADF and NDF that were caused by genetic factors *(*Katić *et al., 2008).* The proportion of leaves in the alfalfa forage might be considered as an indirect indicator of alfalfa quality (Rotili *et al*., 2001). The optimum NDF content of alfalfa forage, 40.13 % of DM was in stage 5 in 2011, and in 2012 in stage 4 (40.56 % of DM). Cool and wet conditions caw delay the flower to open while NDF continues to increase (Găvan *et al*., 2013).

Table 2 Classification of alfalfa hay quality

Quality Standard	CP (%DM)	NDF (%DM)	ADF (%DM)	RFV
0-Prime	>19	<40	<31	>151
1	17-19	40-46	31-40	125-151
2	14-16	47-53	36-40	103-124
3	11-13	54-60	41-42	87-102
4	8-10	61-65	43-45	75-86
5	<8	>65	>55	<75

Source: (Redfearn and Zhang, 2011).

Relative feed value is calculated by estimating the digestibility of the forage dry matter, and how much the cow can eat based on its “filling” capacity. However, cows sometimes perform differently even when fed forages of identical RFV. Variations in the digestibility of the NDF fraction can probably account for these differences.

Feed quality of alfalfa harvested as haylage or hay depends, to a great extent, on the maturity of the stand. With increasing maturity, plant structural carbohydrates, as measured by the ADF and NDF fractions, increase. These fiber fractions represent the more indigestible parts of the plant. As a result, digestibility and energy obtained through fermentation decrease with maturity. Relative feed value (RFV) has been used for years to compare the quality of legume and legume/grass hays and silages (Peter and Alvaro, 2004).

Conclusion : Legumes are important for the livestock feed particularly for dairy and beef sector. Since the major livestock feed sources in Ethiopia is natural pasture and crop residue supplementation of legume feeds as alfalfa is important to boost the sector of cattle. Alfalfa is the king of legume forage species that can adapt vary of agro ecology and found almost everywhere. Alfalfa forage biomass yield and nutritional quality determined by genetic (cultivar difference) and cutting cycle is the major one among other factors. Alfalfa is one of the highest yielding forage legumes. Under irrigation, it can produce 25 to 27 t/ha DM with a production reduced in the 3rd year to 8-15 t/ha DM. The nutritional composition of alfalfa is better than other legume and grass species. Protein content in alfalfa dry matter varies from 18 to 25% depending on the growth stage (cutting cycle), cultivar difference and other factors.

Therefore, production of legume forage like alfalfa is crucial. Before expanding different alfalfa cultivars for farmers, their nutritional values and biomass yield dynamics should be evaluated. Because not all alfalfa cultivars may have equal nutritional value and herbage yield at different cutting cycle.

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