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Review Article

The fodder oat (*Avena sativa*) mixed legume forages farming: Nutritional and ecological benefits

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ABSTRACT

Oat (*Avena sativa L.*) is one of the most important cultivated winter fodder crops for livestock in Nepal, Yet, its production potential is not fully explored in Nepal for different locations and in combination with legumes. One of the major problems in ruminant feeding in Nepal is the shortage of quality fodder during the winter season where oats-legume mixture would play an important role. Oats are better adapted to different soil types and can perform better on acid soils in comparison to other small cereal grains. Intercropping is a traditional farming technique, which is important in farming systems of developing countries but far less widespread in mechanized systems; however, there is an increased interest in intercropping systems for developing sustainable farming systems mostly for grass-legume polycultures. The review concluded that oats in combination with legumes could be a potential model of intercropping to attain an increased forage dry matter (DM) yield without jeopardizing the quality issue, especially during winter and further, it is required to define the optimum management of these grass-legume species such as oats and vetch and oats and pea in various environments such as choice of grasses and legume species, seed rate, sowing time and fertilizer efficiencies, irrigation requirements and increase in herbage quality is possible if the legumes are dominant in grass-legumes mixture . The advantage of oat-legume mix farming is that it may be produced in a wider range of soil classes, which determines the ecological benefits. However, it further requires a series of experiments to conclude in all aspects.

Keywords: Oat, grass-legume mixture, intercropping, fodder, nutritive value, chemical composition

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1. Oat (*Avena sativa L.*)

Oat (*Avena sativa L.*) is commonly known as *Jai* in Nepali and is one of the most important cultivated winter fodder crops. It has been adapted to a wide range of soil types and climatic conditions. It is promising for multi-cut, fits well in farming systems for quality and quantity fodder supply during winter feed scarcity period (December to April). Oat is an erect annual grass with a fairly good tillering habit that attains a height of 1-2 m. The panicles are lax and effuse. The inflorescence may be equilateral or unilateral. The main axis and lateral branches end in a single apical spikelet. The grain is long and slender or spindle-shaped and usually covered with fine hair at the upper end (Devkota *et al.*, 2015). The leaves may have a length of 25 cm and more. Being a grass species, oats have fibrous root system (Relwani, 1979).

In an estimation of FAO (2010/011), oat ranked sixth in the global context of wheat, maize, rice, barley, and sorghum as a food crop and ranked first in the world within the fodder production statistics. Two cultivars of oat (Kent and Swan) were the first introduced oat cultivars in 1965 (Shrestha *et al.,* 2015) in Nepal. Oats have been under testing since the 1970s and grown on a relatively large scale by the Nepalese farmers during the first and second livestock development projects from 1980 to 1994. Since the 1980s, more than hundreds of different oat cultivars were brought from different organizations and countries as a part of forage research and development programs in the country (Pariyar, 2005). Oat growing is concentrated mainly on irrigated land in the Terai and low-hills and on rain-fed land in the low and mid-hills region in the commercial dairy pocket areas. Oats are mainly grown below 1600 m.a.s.l but can be cultivated at higher altitudes (Pariyar, 2002).

They are mainly used as green feed for the winter gap but some are already being made into hay, mainly at higher altitudes. It is well known that fodder oats have the potential to produce nutritious fodder during the dry winter. Thus, the Department of Livestock Services (DLS) started oat cultivation in all seventy-five districts of the country through the distribution of mini kits for winter fodder oats alone and in mixture with legumes such as vetch (both *Vicia bengalensis cv* Popany and *Vicia villosa var. dasycarpa cv* Nemoi were used), pea (*Pisum sativum*) or berseem *(Trifolium alexandrinum*), depending on their suitability for particular areas (Pariyar, 2002).

It was noticed that the oat productivity in Nepal is very low. Kshatri et al. (1993) stated that the average fodder oat production by farmers in the eastern hills was 18-22 ton/ha which was less than the 60 ton/ha obtained in a similar Indian context (Pathak & Jukhmola, 1983). In the farmers managed areas @80:40:20 N: P205: K20 and at two cuttings management system oat cultivars such as Amuri and JHO 822 had produced an average fodder yield of 15.5 ton/ha, and Swan 18 ton/ha (Pariyar, 2003). Though productivity of oat might depend upon the environmental and management factors such as altitude, soil type, rainfall, fertilizer etc., the overall production of fodder oats on farmers' fields was not satisfactory (Pariyar, 2002). In the lower hills, the average production was reported to be 15-20 ton/ha in three cuts while in the

Terai, it was 20-25 ton/ha (Pariyar, 2002). The oat may be grazed, cut-and-carried, or could be used in the form of hay, silage or haylage. The oat may be used as a winter cover to protect soil erosion and to trap N that would otherwise be lixiviated during winter (Sare, 2008). Vetch-oat forage mixtures are particularly popular in the Mediterranean basins (Suttie *et al.*, 2004).

Distribution of oat

Oats are mostly found at 45-65° N and 20-46° S (Stevens *et al.*, 2004). In temperate regions, they are grown as a spring-growing /autumn-growing and as a cool season crop in the Mediterranean and tropical areas (Heuzé *et al.*, 2016). Oats grow on a wide range of soils at temperatures ranging from 5 to 26°C and rainfall over 500 mm (Ecoport, 2013). Further, oats perform better in loam soils but tolerate acidic and low fertile soils with pH ranging from 4.5 to 8.6 (Heuz *et al.*, 2016). Oat has become a major crop in regions such as the Himalayas (Pakistan, North India, and neighboring countries), the southern cone of South America (Argentina, Brazil, Chile, Uruguay) and North Africa. On the contrary, oat yield has declined in areas, notably temperate ones, where mechanized agriculture and maize is grown for silage are possible (Suttie *et al.*, 2004). Oats are grown in more than 50 countries but statistical information is mainly concerned with the food-grain (Heuzé *et al.*, 2016). Although oats are grown as a dual crop (forage and grain), their introduction in the commercial market is rare. However, there is no reliable estimation of worldwide oat forage acreage and production in general (Suttie *et al.*, 2004).

Oats remain an important grain crop for people in marginal ecologies throughout the developing world, and also in developed countries (Suttie & Reynolds, 2004). Livestock grain feed is still the primary use of oat crops, accounting for an average of around 74 percent of the world's total usage in 1991 to 1992 (Welch, 1995). Stevens *et al.* (2004) found that oats are well adapted to a wide range of soil types but perform better on acid soils. They are mostly grown in cool moist climates and can be sensitive to hot, dry weather from head emergence through to maturity (Suttie & Reynolds, 2004). Oats are now a very important winter fodder on small farms in Pakistan and northern India; some of this is described in Dost (2004). Oats are grown widely throughout Punjab in late winter through spring yet none are reported in FAOSTAT for India, Pakistan or neighboring countries. Stevens *et al.* (2004) noted that Russia, countries of the former Soviet Union, the United States, Canada, Germany, and Poland account for about 75 percent of the world's supply of grain, seed, and industrial grade oats. Since the 1960s, the proportion of oats used for feed has declined in the US and Canada, remained unchanged in the former Soviet Union countries and Poland, and increased slightly in Germany (Stevens *et al.*, 2004). The leading export countries of oat grain are Canada, Finland, Sweden, Australia, and Argentina.

Oat-legume associations

Oat as fodder can be sown in mixture with a legume such as a Vetch (*Vicia sp*.), pea or berseem (Ross *et al.*, 2004; Undersander, 2003; Johnston *et al.*, 1999). Oats with legumes is effective for reducing diseases, controlling weeds, occupying the greater share of available resources and improving the nutritive value of the crop compared to oats alone, though DM yields are not necessarily improved (Undersander, 2003). Oat-vetch associations are important in the

Mediterranean basins, though they have declined during the 2000s in the Maghreb due to lack of availability of vetch seeds, making a more complex crop management system necessary (Anil *et al.,* 1998).

Uses of Oat

Animal Feed

It is preferred feed of all animals and grain is also valuable feed for horses, dairy cows, poultry and young breeding animals. The demand for meat, beef, milk, butter, and their byproducts is increasing due to the rapidly growing human population (Ahmad *et al.,* 2014). Oats are grown for use as grain as well as forage and fodder. It is an important winter fodder, mostly fed as green but excess is converted into silage or hay for animal feeding during fodder deficit periods (Suttie & Reynolds, 2004). Oat protein is nearly equivalent in quality to soy protein, which has been shown by the World Health Organization to be equal to meat, milk, and egg protein (Ahmad *et al.,* 2014). It is obvious that the farmers have to face fodder shortage problem in winter when they have only dry stalks of summer cereal fodders or dry summer grasses. In order to increase productivity per unit area, there is a need to develop promising cultivars having high forage yield potential and quality (Ahmad *et al.,* 2014). Suitable Fodder combinations i.e. grass-legume combinations s such as oats + vetch and oats + peas), commercial dairy farmers and resource-poor farmers have greatly reduced the feed shortage problem and reduced the cost of feed to a great extent (Pariyar, 2002). Interest in oat hay for the dairy, feedlot and horse industries has grown in recent years.

Oat as an intercrop with legumes

Intercropping is a traditional and extensive agricultural practice used in low input cropping systems in the world (Anil et al., 1998). During the 20th century, there was a shift from mainly labor-intensive systems to more optimized cropping through the use of external inputs, especially synthetic fertilizers, and pesticides (Crews & Peoples, 2004). There has been a growing interest in intercropping systems in developed countries due to the increasing awareness of environmental degradation arising from the heavy use of non-renewable resources (Fujita *et al.,* 1992). Intercropping systems, especially cereals with legumes, have several major benefits such as higher total yield and better land use efficiency (Dhima *et al.,* 2007), yield stability of the cropping system, better utilization of light, water, and nutrients (Javanmard *et al.,* 2009), improved soil conservation (Anil *et al.,* 1998), and better control of pests and weeds (Banik *et al.,* 2006; Vasilakoglou *et al.,* 2008).

Merits of grass-legume intercrop other examples

Increased production

Production is more than a pure cropping of the same land amount (Caballero & Goicoechea, 1995). Ghanbari and Lee (2002) reported that dry matter production in wheat and beans intercrops had been more than their pure cropping. Similarly, Martin and Snaydon (1982) reported that grain and dry matter yield in bean and barley intercrops were more than their pure cropping. Odhiambo and Ariga (2001) found that there was increased production with maize and

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beans intercrops in different ratios due to reduced competition between species compared competition within species. Willey (1990) considers intercropping as an economic method for higher production with lower levels of external inputs. More production in intercropping can be attributed to the higher growth rate, reduction of weeds, reduced pests and diseases and more effective use of resources due to differences in resource consumption (Eskandari, 2012b; Eskandari *et al.*, 2009b; Watiki *et al.*, 1993; Willey, 1990; Willey, 1985). In addition, the production increases in intercropping if there are complementary effects between the components of intercropping have been achieved by intercropping which reduce the competition between them (Mahapatra, 2011; Zhang & Li, 2003; Willey, 1979b).

Greater use of environmental resources

The benefits of intercropping in the crop production in comparison with pure stands are due to the interaction between components in intercrops and the differences in competition for the use of environmental resources (Mahapatra, 2011; Valdez and Fransen, 1986). If the intercrops components have a difference together in use of environmental resources, so that are complementary in use of this resources, thus resources use is more effective than a pure stand, and the resultant increases in yield (Jensen, 1996).

It was found also reported that competition between species in maize and peas' intercrop was less than competition within species. Wahua (1983) found that nutrient uptake by intercropped maize and cow pea, was higher than pure stand, and intercrops components were complementary in the use of resources (Eskandari & Kazemi, 2011; Eskandari *et al.*, 2009b).

Reduction of pests, diseases and weeds damage

The other benefits of intercropping are its ability to reduce pest and disease damage. In a review by Francis (1989) on intercropping, in 53% of the experiments intercropping reduced the pest, and in 18% increased the pest than the pure stand. Increasing pests can be due to several reasons, such as the second crop is a host for pests in intercropping, or increasing the shade in the canopy, provides favorable conditions for pests and pathogens activity. In addition plant residues can be as a source for pathogens inoculated (Anil *et al.*, 1998; Watiki et *al*., 1993). In mono-cropping systems, available resources such as soil moisture, nutrients, and light are rarely used by the plant and thus released niche are occupied by the weeds. In intercropping, there is better utilization of nutrients, soil moisture, and light and fill the empty niche which leads to the weed suppression (Saudy & El-Metwally, 2009; Altieri, 1995).

Improve soil fertility and increase in nitrogen

Intercropping improves soil fertility and increases the nitrogen content. And the resulting nitrogen is an essential element for soil fertility and plant growth.Several reports indicate that the increase in nitrogen content of non-legume plants is due to intercropping of these plants with legumes (Eskandari *et al.,* 2009a; Anil *et al.*, 1998; Fujita *et al.*, 1992). Rhizobium bacteria have a symbiotic relationship with plants of Leguminosae family and thereby can fix atmospheric nitrogen into available nitrogen for plants uptake.

Demerits of grass-legume polyculture

The grass-legume association is particularly complex because the components intermingle competitively and the transfer of N from the legume to grass contributes to the complex interaction between them. Further, the ideal environment for the growth of both the grass and legumes may vary and the *Rhizobium*-legume association also has particular requirements. Management, especially the grazing behavior of animals, may also influence the association and in turn, the composition of the sward may influence the animal in terms of the amount of nutritive value (Laidlaw & Teuber, 2001). The compatibility of grasses with legumes depends on the morphology and physiological characteristics of the grass and legume, the response of each to management and the climate, and soil and biotic factors under which the crop is growing. In the temperate world, grasses grown with white clover are more compatible with the ecotypes of white clover with which they were growing naturally than with other types of white clover and, indeed *Rhizobium* (Expert *et al*., 1997). The demerits of grass-legume mixture include difficulty in management and harvesting of the mixtures, higher seed cost etc. have been reported by many workers.

2. Field pea (*Pisum sativum* L.)

It is an important crop and can be grown successfully in Terai (<100 m) during winter to a high mountain (3000 m) during summer months. Peas are grown alone or in combination with cereals for silage and green fodder (Elzebroek & Wind, 2008). Peas and other legumes are desirable in crop rotations because they break up disease and pest cycles, provide nitrogen, improve soil microbe diversity and activity, improve soil aggregation, conserve soil water, and provide economic diversity (Lupwayi *et al.,* 1998; Biederbeck *et al.,* 2005; Chen *et al.,* 2006). Pea is grown with cereal crop like oat to enhance the forage quality.

Description

The pea is a rapid-growing herbaceous legume with angular or roundish hollow stems covered with a waxy bloom. The plant has a taproot that can grow as deep as 1 m with numerous lateral roots. Leaves are alternate, a compound with 1-3 pairs of leaflets borne on petioles with several pairs of tendrils. Large leaf-like stipules are inserted at the base of the leaves (FAO, 2011; Muehlbauer *et al.,* 1997; Oelke *et al.,* 1991). The inflorescence is a raceme that bears white, pink or purple flowers. Pods are dehiscent and contain several seeds that may be globular or angled, smooth or wrinkled (FAO, 2011; Muehlbauer *et al.,* 1997). Peas are a high-yielding, short-term crop with high protein content (Fraser *et al.,* 2001). *Pisum sativum* has a large genetic diversity. There are winter and spring varieties, leafy and leafless, early- or late-maturing (Heuzé *et al.*, 2015b). Seeds can be of varying color, shape and size. Pea varieties can be classified into garden peas (green peas are eaten as vegetables), field peas (dried peas for feed and food) and **forage peas**, that are grown primarily for forage. An example of the latter varieties is the Austrian Winter Pea. However, pea varieties can be multi-purpose. Pea can also be used for green manure (Maxted *et al.*, 2001; Oelke *et al.,* 1991).

Adaptation

Peas are adapted to many soil types, but perform best on fertile, light-textured, well-drained soils (Hartmann *et al.,* 1988; Elzebroek & Wind, 2008). Peas are sensitive to soil salinity and extreme acidity. The ideal soil pH range for pea production is 5.5 to 7.0 (Hartmann *et al.,* 1988). Peas grow well with 16 to 39 inches annual precipitation (Elzebroek & Wind, 2008) and that could be

Mixture of oat and pea

Intercropping of annual crops such as pea+oat or pea+barley is the traditional system of well enough in mixture with grasses such as oat. In many countries. Peas are important feed grain legumes for animal production and are widely grown for hay, pasture or silage production either alone or mixed with cereals (McKenzie & Sponer, 1999). Peas grown as a monocrop, result in reductions in forage and seed yield due to severe lodging after flowering (Stelling, 1997). Thus, peas are often sown in mixtures with cereals that have an upright stature (Uzun & Acikgoz, 1998). Tall varieties of pea are cultivated with cereals, to reduce lodging and increase hay yield and quality (Robinson, 1960; Anderson, 1975; Droushiotis, 1989; Tan & Serin, 1996).

Various factors such as the selection of plants, mixture rates and stages of cutting are very important in legume-cereal mixed cropping. Legume-cereal mixtures are important protein and carbohydrate sources for livestock (Karadag & Buyukburc, 2003). In past, many studies were conducted to determine the suitability of crops in a pea mixture, and variable results were attained. There have been repeated reports that the mixed cropping pea with oat increased hay yield (Robinson, 1960; Mitchell, 1983), while in other studies reported that pea with barley should be mixed (Chapko *et al.,* 1991) as polyculture. Seed rates during sowing legume-grass are important in mixed cropping for high yield and fodder value. The cereal ratio in the hay can be higher than the sowing ratio. The plant density of cereals are high in the hay due to their characteristic of tillering and the hay yield; while crude protein ratio and yield decrease (Kwabiah, 2004; Geijersstam & Martensson, 2006).

3. A mixture of Oat and Vetch

The common vetch (*Vicia sativa*) is an important legume that can be successfully grown in both terai and mid hills and it is noted for its ability to fix large quantities of nitrogen that is about 110 kg N per hectare (NPAFC, 2073/2074). It is grown for hay, pasture, silage, seed, or as interim cover on disturbed soil. *V. sativa* provides palatable forage (fresh, hay and silage) and grain to livestock of monogastric species (including humans). Common vetch also provides a valuable cover crop and green manure (Sattell *et al.,* 1998).

Common vetch (*Vicia sativa L*.) is an annual legume, which is usually grown in mixtures with small grain cereals for hay or forage production. It has climbing growth habit and high levels of protein. These mixtures improve growth conditions and enhance forage quality (Anil *et al.,* 1998; Heuzé, 2015a). Common vetch or grasses alone do not provide satisfactory results for forage production (Osman & Nersoyan, 1986). Common vetch is low-yielding, particularly in areas with low rainfall (Hadjichristodoulou, 1978) and hinders harvest because it normally spreads on the soil surface (Robinson, 1960). On the other hand, small grain cereals provide high fodder yields in terms of dry weight but they produce low-quality forage. (Lawes & Jones, 1971).Forage quality of cereal hay is usually lower than that required to meet satisfactory production levels for many categories of livestock. In mixtures, companion cereals provide structural support for common vetch growth improves light interception, and facilitate mechanical harvest, whereas common vetch in mixtures improves the forage quality (Thompson *et al.*, 1992). The other advantages of mixtures of Vetch and grasses include greater uptake of water and nutrients, enhanced weed suppression, and increased soil conservation (Stern, 1993; Ranells & Wagger, 1997; Anil *et al.*, 1998). Caballero & Goicoechea (1986) and Thomson *et al.* (1990) reported that the most suitable cereal for mixtures with common vetch is oat (*Avena sativa L.*). Intercropping oats with forage legumes such as vetch improves both the quantity and the quality of the hay (Khalili *et al.*, 1992; Umunna *et al.*, 1995). There have been several reports that supplementation of oat-vetch hay with concentrates or with a high protein forage legume hay increased milk production in crossbred cows (*Bos taurus* × *Bos indicus*) (Khalili *et al.*, 1994; Khalili *et al.*, 1992; Mpairwe *et al.*, 2003).

Dry matter yield of forage species and their mixture

Grass-legume combination plays a key role in higher dry matter productivity. The quantitative changes in the herbage productivity and chemical composition have been documented in various research when different legumes like vetch and pea are grown in combination with oats. The findings of dry matter productivity for vetch as monoculture and vetch with oat has brought similar records to the findings that dry matter yield in vetch mixture with oat (50% vetch: 50% oat) was higher than pure vetch sowing and 25% vetch: 75% oat combination was most productive (Tuna & Orak, 2007). The common vetch with triticale, the forage yield was lower by 18% than that in mixtures of common vetch with oat (Lithourgidis *et al.*, 2006). Forage legumes monoculture has many issues with herbage productivity for the reasons that they yield less. Similarly, in comparison of pea mixed with oat and pea monoculture, the oat pea mixture herbage productivity was higher than pea monoculture at all harvests. A similar result was found in a research study where the dry matter yield of pea oat mixture was higher than the pea at all harvests (Kaiser *et al.*, 2007). There have been repeated reports on the higher yield of forage polyculture (grass-legume mixture over grass and legume monocultures respectively (Sıma *et al.*, 2010; Albayrak & Ekiz, 2005; Berdahl *et al.*, 2001; Gökkuş *et al.*, 1999). The basic reason for higher forage herbage productivity might be due to the utilization of symbiotically fixed nitrogen (Whitehead, 1995), more enhanced interception of light (Hay & Walker, 1989) and allelopathic (Pudnam & Duke, 1978) and some other effects. These factors created a micro-environment that favored higher yields than those obtained from sole legume or grass stands (Sengul, 2003). Besides, legumes can cover the N demand of grasses from atmospheric N_2 and therefore legumes intercropped with grasses compete for less for soil mineral nitrogen. Eskandari *et al.* (2009a) indicated that there was an increase in forage quality than cereal mono-crop and an increase in dry matter in comparison to legume monoculture. Several studies showed that the dry matter yield increased with the increasing rate of oat in mixtures of oat with annual legumes (Walton, 1975; Osman & Nersoyan, 1985). Furthermore, Mitchell (1983) showed that the oat substantially supported the pea plants in such mixtures and provided most of the dry matter production.

In most oat –legume studies, the most combinations yielded more herbage than when grown as a pure legume sward at each of the three harvest times. The pea–oat combination was the most productive than oat-vetch combination as the mean dry matter yield was higher than that of vetch mixture with oat. In most cases, the inclusion of oats with legumes significantly increased total herbage yields relative to legume monocultures, and this is consistent with other studies with vetch (Munzur,1993; Wassermann *et al.*, 1984) and pasture legumes (Martiniello,1999; Wassermann *et al.*,1984; Wiersma *et al.,* 1999). Research findings of Lauriault and Kirksey (2004) revealed yield reduction of the grass-legume mixture- wheat in mixture with hairy vetch and pea but it was still higher than the yield of oat, barley and rye monocultures or in mixture with legumes. Although legume-grass mixtures produced the highest total DM, where maximizing quality or production of N for following crops is the primary objective, previous findings of the experiments indicated that legume monocultures would be the preferred options. However, when sown alone, both species are susceptible to lodging and a small cereal component which can act as a climbing frame may be desirable to minimize this problem. However, our results did not show the number of peas and vetch damaged by lodging in the present study.

The chemical composition of forage species and their mixture

Crude Protein

The crude protein content of forage is one of the most important criteria for forage quality evaluation (Caballero et al., 1995; Assefa & Ledin, 2001). The use of grass-legume mixture can increase the fodder yield and quality (Sturlud ottir *et al.*, 2013). Jannink *et al.* (1996) found that vetch mixture had much higher CP content than pea and oat alone. Research has shown that oats grown with peas can provide excellent tonnage and high-quality forage. Including peas in the mixture generally increases crude protein (CP) by 2 to 4 percentage units (Owens eta l., 2007). Herbage nutritive value of forage grasses and legumes is negatively related to DM accumulation (Bélanger *et al.*, 2001). Thus, increases in herbage DM yield are expected to result in a decrease in nutritive value of mixture than legume monocultures pea and vetch. Haq et al. (2018) reported that the CP content of the oats-vetch mixture, oats-pea mixture was higher than the oats grown alone, while it was lower than legume monocrop pea and vetch. Legume-cereal intercrops may produce higher grain and protein yields as compared to the respective cereal sole crops (Jensen, 1996; Hauggaard-Nielsen *et al.,* 2001; Lauk & Lauk, 2005) and show greater yield stability across years than when growing legumes and cereals as sole crops (Willey, 1979a; Ofori & Stern, 1987). Legumes as sole crops can are grown under organic farming conditions, but they have some disadvantages compared to legume-grass intercrops. Sole crops of common vetch and other leafy long-straw pea varieties may often lodge heavily, and this could be prevented by mixed cropping (Aysen & Asik, 2012).

CONCLUSION

In conclusion, cereal-legume crops show a considerable potential for herbage productivity in abandoned lands with minimum tillage and are likely to play a crucial role in providing weed control in mixed grain and livestock enterprises as well. Grass-legume mixture could significantly increase the DM and nutritive value, suggesting a better option to utilize per unit area of land for a maximum DM harvest without jeopardizing the quality issue and with the potential to minimize weed infestation. Oats in combination with pea and or vetch could be a potential model of intercropping to attain an increased forage DM yield that could address the situation of mitigating DM shortage, especially during winter season. This combination could be successfully extrapolated at farmers' field. The following recommendations have been made for improving and adopting grass-legume mix farming for better fodder quality in the ecological footprints:

a) Increases in herbage quality would be possible if legumes are dominant in grass-legume mixtures, and that would also need a series of experiments to conclude research.
b) It is required to define the optimum management of these grass-legume species oats and vetch, oats, and pea in various environments such as choice of grasses and legume species, sowing rate, sowing time and fertilizer efficiencies and irrigation requirements etc.
c) Findings from review papers indicated that the oats in combination with pea or vetch could be a potential model for intercropping to attain an increased forage DM yield that could address the situation of mitigating DM shortage, especially during winter. Thus, further research and review should be carried out covering round the year assessment and quality analysis of forage mixture in order to manage the abandoned land with minimum tillage to improve the quality as well as herbage production.

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Author Contribution

The author himself designed and revised the manuscript for publication. Further consultation was done with Prof. Dr. Naba Raj Devkota for detailed review.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this review paper.

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