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Review Articles

Research Articles

Research Article

PRODUCTIVITY AND CHEMICAL COMPOSITION OF OAT-LEGUMES MIXTURES, AND LEGUME MONOCULTURE IN SOUTHERN SUBTROPICAL PLAINS, NEPAL

S. Dangi, N. R. Devkota, and S. R. Barsila*
Agriculture and Forestry University, Rampur, Chitwan, Nepal

ABSTRACT

Oat (*Avena sativa L.*) is grown in Nepal for last hundred years; though its production potential is yet to be explored to combat the winter forage scarcity. The oats can be grown in combination with other fodder legumes such as berseem, lucerne, pea, and vetch. In order to increase productivity per unit area, there is a need to test the promising forage species having high forage yield potential and quality as well the compatibility for mix cropping. This study was designed to determine the productive potential of oat combined with promising legumes in terms of dry matter and chemical composition. A field experiment was done at AFU livestock farm to determine the dry matter productivity and the chemical composition of oat (*Avena sative*, variety Netra) +vetch (*Vicia sativa)*, oat and pea (*Pisum sativum)*, pea and vetch monoculture, respectively, and were replicated four times in field plots with 6× 6 m^2 by following RCB design. Individual plots was prepared by plowing the field prior to sowing the seeds and further, the standard agronomic practices was followed to establish the forage stands. The forage mixture, harvesting time and their interaction were considered as major factors of analysis for dry matter productivity and chemical constituents such as CP, CF and EE. Results showed that only harvesting time had a significant effect ($p<0.05$) on oat tiller numbers while harvesting time, forage mixture and interaction had a significant effect on legume branches. Both the harvesting time and forage mixture had a significant effect on forage dry matter productivity ($p<0.05$). The highest mean dry matter yield was obtained from oats and pea combination (0.89t/ha), or oats and vetch (0.86t/ha). There was a significant variation in CP, and CF content across the harvest regimes. This study results had shown that oats-legume mixture would have the potential to increase herbage productivity and this practice can be established in abandoned lands with minimum tillage. Oats in combination with pea, and, or vetch could be a potential model of intercropping to attain an increased forage DM that could be successfully extrapolated at farmers' field.

Key words: herbage productivity, oats, vetch, pea, nutritive value

INTRODUCTION

Agricultural lands in Nepal provide about 60% of the total annual feed supply, mainly in the form of low-quality crop residues while forest and grazing lands provide the rest. However, the total feed dry matter deficit and total green roughage deficit in the country are about 30.8% and 54.3%, respectively (Pariyar, 1993; Pande, 1997; Raut, 1998) and winter season is the main season of feed deficit in the country. With the introduction of new agriculture management practices (appropriate rates of manure and fertilizers, promising cultivars, better non-legume and legume combinations) , commercial dairy farmers and resource-poor farmers have greatly reduced the feed shortage problem during the dry winter months and have achieved 30% feed cost reduction in the recent past years(Pariyar,2002). 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 with quality per unit area, there is a need to develop promising cultivars having high forage yield potential and quality (Ahmad, Dar, and Habib, 2014). The Oat is mostly fed as fresh green but the surplus is converted into silage or hay during fodder deficit periods (Suttie and Reynolds, 2004). Besides, oats are quick growing, palatable, succulent and nutritious and compatible with other winter fodder legumes such as berseem, Lucerne, pea, and vetch.

At present oat cultivation is concentrated mainly in Khetland (irrigated land) of Terai and low-hills and in the Bariland (rain-fed) of both Low and Mid-hills regions.The production of high-protein and more nutritious hay (Jung et al., 1991; Sengul, 2002) and reduced nitrogen inputs (Whitehead, 1995) would have made grass-legume mixtures beneficial. The beneficial effects of mixtures further might be varied with sowing methods and mixture combinations (Altin & Go¨kkus, 1988).Cultivation of mixtures contributes to the complementary use of habitat resources and differentiation in the size and depth of the root systems of

* Corresponding author: srbarsila@afu.edu.np.

cereals and legumes allows them to utilization water and nutrients from different soil layers that ultimately increases productivity and greater stability of yield. Under this context an experiment was done to determine productive potential of oats in combination with promising fodder legumes to estimate their DM production and chemical constituents.

MATERIALS AND METHODS

Study Site: The field experiment was conducted at Agriculture and Forestry University Livestock Farm, Rampur, Chitwan, Neapl. The experimental site was situated between 84º 20' east longitudes to 27º39' north latitude and was182 m.a.s.l. The field experiment was conducted from December 2016 to March 2017.

Land preparation:The experimental plots were prepared by ploughing the plots 12 days prior to sowing seeds with the tractor. Stubbles, weeds, and residues in the field were removed prior to sowing seeds to make seedbed fine. The layout of the field was done by making 16 plots each having 6 X6 m^2inRCBdesign manually using tapes, spades, and stakes.

Fertilizer application:NPK was applied @100:60:40 kg/ ha and farmyard manure (FYM) @10 ton/hectare was used. For that a half of N and all the P and K fertilizers and allFYM were usedduring land preparationbefore seeding by broadcasting and rest half of N fertilizer was used at 21st days after seeding after irrigation.

Seed rate, Sowing, and Irrigation: The seed was sown using the broadcast method. Seed rate used was -oats: 80@ kg/hectare; vetch @ 20 kg/hectare in mixture with oats and pea-@30 kg/hectare in mixture with oats was used. For intercropping half of the seed rate requirement was used respectively for oat and legumes.

After sowing, the plots were irrigated once and then second irrigation was done at 21stdays after sowing (DAS) the seed.

Climate record: The climatic recordings were taken from Department of Hydrology and Meteorology, Rampur, Chitwan. Maximum and Minimum temperature (ºC) and rainfall (mm) during the experiment period have been illustrated in Table1.

Table 1. Average monthly maximum and minimum temperature, rainfall during research period at NMRP, Rampur, Chitwan, Nepal, 2016/17

Year (2016/2017)	Max Temp (ºC)	Min Temp (ºC)	Rainfall (mm)
October	31.98	19.66	1.52
November	28.7	11.03	0.00
December	23.81	8.88	0.00
January	24.03	5.95	0.49
February	26.67	10.14	0.12
March	29.39	12.52	2.11

Source: Department of Hydrology and Meteorology, (2017).

Sampling design, data collection, and analysis

Ten plants were taken randomly from each plot to record morphological characteristics one day before herbage sampling. Further, data recording was taken on different parameters such as tiller (for oat) and branches per plant (legumes), green matter yield perplot ateach cutting. Altogether three cuttings were taken at different dates (1st cut in January 7,2nd cut on February 27 and 3rd cut on March 27, 2017). The sample aliquot was calculated based on DM and individual chemical composition i.e. CP, CF, and EE for the mix plots and a single value of composition were thus obtained by using the following formula:

CP = (Dry weight of grass) / (Total dry weight of the mixture) × %CP of grass
+ (Dry weight of legume) / (Total dry weight of the mixture)
× % CP of legume

Analysis of data was done by using R software version 0.98.501-. ©2009-2013 R Studio, Inc. and mean comparison was setby Duncans Multiple Range Test (DMRT). The effect of harvesting time and forage

mixture on morphologicaltraits, dry matter productivity and chemical composition was determined using linear statistical model for two factors which were given by:

$$Yijk = \mu + \sigma i + \beta j + (\rho\beta)ij + \in ijk$$

μ = constant factor

σi = effect of ith level of harvesting time

βj = effect of ith level of forage mixture

$(\rho\beta)$ = interaction effect of harvesting time & forage mixture

$\in ijk$ = random error

RESULTS

Morphological traits

The effect of harvesting time, forage mixture and the interaction effect to the number of branches in legumes was significant ($p<0.005$) at all harvests (Table 2).The highest number of branches observed was in vetch (16 branches/plant) followed by pea (14 branches/plant) at 3rd harvest., whilst it was the lowest in pea mix with the oat (7 branches/plant) at 1st harvest.

Accordingly, only the harvesting time remained significant ($p<0.05$) fortiller count of oat (table 2).The highest tiller obtained was 7 tillers/plant in oat and vetch combination at 2ndharvest, followed by oat and pea combination which was 6 tillers/plant at the same harvest. The details of morphological traits measured for forage species and mixture has been summarizedin table2.

Table 2. Morphological performance of forage mixture

Branches/Tiller		**Branches Legumes**			**Oat tiller**	
Forage mixture	Oat+ Vetch	Pea	Vetch	Oat+Pea	Oat+Vetch	Oat+Pea
1st harvest	7.32^{e}	7.70^{e}	8.60^{de}	6.72^{e}	4.75^{a}	4.20^{a}
2nd harvest	8.85^{de}	11.45^{c}	11.87^{bc}	10.45^{cd}	6.70^{a}	6.08^{a}
3rd harvest	11.15^{c}	13.67^{b}	15.67^{a}	10.35^{cd}	5.72^{a}	4.45^{a}
***p*-value**						
ht	<0.001				0.032*	
fm	<0.001				0.15	
ht*fm	0.032*				0.84	
s.e.m	0.02				0.01	

Mean difference set by DMRT, ht=harvesting time, fm=forage mixture, s.e.m= standard error of the mean, different superscripts within the row and column indicated difference at p<0.05. Oat represents variety Netra.

Above ground herbage productivity

The harvesting time and forage mixture had a significant effect ($p<0.05$) on productivity (table3), while interaction effect was similar ($p>0.05$).The highest dry matter productivity was observed was 0.36 t/ha in oat and vetch combination at 3rd harvest and oat and pea at the 2nd harvest respectively. The lowest DM yield was observed for pea (0.12t/ha) and vetch (0.16t/ha) at 1st harvest. The detail of forage species and their mixture used in this experiment to measure the productivity has been prescribed in (table3).

Overall mean calculation of each grass-legume mixture and the monoculture pea and vetch suggested that the highest mean dry matter yield was 0.89t/ha in the grass-legume mixture (oat and pea combination) which was rather similar to oat and vetch combination (0.86t/ha). The trend was much similar for legumes monoculture as it was observed that for vetch (0.65t/ha) and 0.59 t/ha in pea monoculture.

Table 3. Productivity of forage and forage mixture (t/ha)

Treatments	Oat+Vetch	Pea	Vetch	Oat+Pea
1st harvest	0.21^{de}	0.12^{f}	0.16^{ef}	0.21^{de}
2nd harvest	0.29^{bc}	0.21^{de}	0.25^{cd}	0.36^{a}
3rd harvest	0.36^{a}	0.26^{cd}	0.24^{cd}	0.32^{ab}
Total	0.86a	0.59b	0.65b	0.89^{a}
***P*- value**				
ht	<0.001			
fm	<0.001			
ht×fm	0.063			

Mean difference set by DMRT, ht=harvesting time, fm=forage mixture, different superscripts within the row and column indicated difference at p<0.05.

Chemical Composition of forage species and their mixture

Crude protein

The harvesting time and forage mixture had a significant effect ($p<0.05$) on the crude protein content of the herbage while interaction effect was non-significant (table4). The highest CP content was found in legumes (16% on an average) at 1st harvest, while the trend remains similar up to 2nd and third harvests respectively. The trend of CP content was in declining from first to the third harvest, as expected from the plant maturity point of view. The details of CP content of herbage harvested for legumes and grasses at mono and polycultures respectively has been shown in table 4.

Crude Fiber (CF)

The effect of harvesting time, forage mixture, and interaction effect was significant ($p<0.05$) on the crude fiber content (CF) of and their mixtures respectively (table4).

The highest crude fiber content observed was 29.12% in grass-legume combination oat and vetch at 2nd harvest followed by the same mixture (29.02%) at 3rd harvest. The lowest crude fiber content was found in Pea (25.27%) at 1st harvest. The similarity in crude fiber content was found in monocultures of 1st and 2nd harvest of monocultures pea and vetch (table4).

Ether extract (EE)

The harvesting time, forage mixture and interaction had a significant effect ($p<0.05$) to the EE of forage species and their mixture (table4).Statistically, similar ether extract content was found in pea and vetch (3.0 -3.20%) across all the harvesting times.The highest ether extract observed was 3.20% in vetch monoculture, while the lowest ether extract (2.56%) was recorded in grass-legume mixture with oat and pea combination (table4).

Total Ash (TA)

The harvesting time, forage mixture and interaction had a significant effect ($p<0.005$) on TA content of forage species and their mixture (table4). The highest total ash content observed was 7.60% in oat and vetch at 3rd harvest. This was followed by oat and pea combination at the same harvest (7.32%).The lowest total ash content was 5.55% in pea monoculture at 1st and 2nd harvest.

Table 4. Chemical composition of forage species and their mixture

%constituents	%CP			%CF				%EE				%TA			
Treatments	Oat+ Vetch	Pea	Vetch	Oat+ Pea	Oat+ Vetch	Pea	Vetch	Oat+ Pea	Oat+ Vetch	Pea	Vetch	Oat+ Pea	Oat+ Vetch	Pea	Vetch	Oat+ Pea
1st harvest	12.80^{bc}	15.43^{a}	16.24^{a}	13.06^{bc}	27.45^{c}	25.27^{f}	25.65^{f}	26.91^{cd}	2.93^{cd}	3.10^{ab}	3.2^{a}	2.95^{bcd}	6.38^{c}	5.55^{f}	5.80^{ef}	6.47^{c}
2nd harvest	10.91^{d}	13.28^{bc}	13.95^{b}	12.0^{cd}	29.12^{a}	25.65^{f}	25.97^{ef}	28.17^{b}	2.83^{d}	3.02^{bc}	3.07^{abc}	2.84^{d}	6.38^{c}	5.55^{f}	5.80^{ef}	6.47^{c}
3rd harvest	9.43^{e}	11.15^{d}	11.26^{d}	9.18^{e}	29.02^{a}	26.37^{de}	28.22^{b}	28.59^{ab}	2.6^{e}	2.92^{cd}	2.67^{e}	2.56^{e}	7.60^{a}	5.85^{def}	6.92^{b}	7.32^{ab}
***p*-value**																
ht	<.001			<.001				<.001				<.001				
fm	<.001			<.001				<.001				<.001				
ht×fm	0.603			0.00034				0.0359				0.0301				
s.e.m.	0.32			0.20				0.03				0.10				

Mean difference set by DMRT, ht=harvesting time, fm=forage mixture, different superscripts within the row and column indicated difference at p<0.05.

DISCUSSION

Dry matter productivity

Grass-legume combination plays the key role in higher dry matter productivity with improved crude protein content. Quantitative changes in the herbage productivity and chemical composition have been confirmed and documented in the present study when different legumes such as vetch and pea in combination with oats. The present study also demonstrated that the harvesting time and forage mixture had the significant effect on herbage productivity (table3) while interaction effect was not significant. Forage legumes monoculture has many issues with total productivity for the reasons asthey produceless. 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 (Tuna &Orak, 2007). This could obvious that grasses could result in higher dry matter productivity than legumes. A similar trend of findings had also been reported by Haq et al. (2018) in which the oats- vetch mixture dry weight productivity was found to be 2 times more than pure vetch sowing.

The legumes or grass species compatibility would further impact the dry matter productivity. In mixtures of common vetch with triticale, forage yield was lowered by 18% than that in mixtures of common vetch with oat (Lithourgidis et al., 2006). Common vetch or cereals alone do not provide satisfactory results for forage production (Osman and Nersoyan, 1985). Vetch is itself a low-yielding, particularly in areas with low rainfall and hinders harvesting. Similarly, in comparison of pea mixed with oat and pea monoculture, the oat pea mixture dry matter yield was higher than pea monoculture at all harvests. A similar finding was found in a study where the dry matter yield of pea oat mixture was higher than the pea at all harvests (Kaiser, Dear &Morris, 2007). Similarly, Haq et al. (2018) reported that the dry weight of oats pea mixture was higher than pea alone. There have been several repeated reports on the higher yield of forage polyculture (grass-legume mixture over grass and legume monocultures respectively (Albayrak &Ekiz, 2005; Berdahl et al., 2001; Gokkus et al., 1999).The basic reason for higher herbage productivity in grass-legume polyculture might be due to the utilization of symbiotically fixed nitrogen (Whitehead, 1995), more enhanced interception of light (Hay & Walker, 1989) and allelopathic and some other effects, though these contributing factors to both quantity and quality has not been recored in the present study. These factors would have 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. A similar result was found by Eskandari et al. (2009), which indicated there was an increase in forage quality than cereal mono-crop and increase in dry matter in comparison to legume monoculture. Several studies had further shown that the dry matter yield increased with the increasing rate of oat in mixtures with annual legumes (Walton, 1975; Osman and Nersoyan, 1985), however, the present study lacks more information regarding the seed rate. Furthermore, Mitchell (1983) indicated that the oat substantially supported the pea plants in such mixtures and provided most of the dry matter production.

In the present study, oat-pea mixture had demonstrated contrasting results to some of the past workers'

findings. Research findings of Haq et al. (2018) showed that oats-vetch combination was found productive than oats-pea combination which however in the present study could not be matched. Based on present results oat-pea mixtures would be expected efficient in terms of dry matter productivity. 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 (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 a grass-legume mixture as 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.

As expected, there was an increase in the dry matter productivity in the 3rdharvest that might be due to the increasing dry matter production of the herbages with the delay of harvesting stages. The increase in DM productivity with prolonged growing duration was obvious and might have attributed by lignifications thereby increased cell wall contents with advanced maturity (Salawu et al., 2001; Alemu et al., 2007; Ayub et al., 2008; Ammar et al., 2010; Atis et al., 2012b).

Chemical composition

The crude protein content of forage is one of the most important criteria for forage quality evaluation (Caballero et al., 1995; Assefa & Ledin, 2001).It has been well perceived from the results of the present study that the use of grass-legume mixture can increase the fodder yield and thus the CP yield could also be expected. From the present study findings, it could be concluded that the crude protein of grass-legume mixture- oat andvetch, oat and pea mixture decreased with the increases in the dry matter allocation at a later stage of harvests. It has been well established the fact that the herbage nutritive value of forage grasses and legumes is negatively related to DM accumulation.

Haq et al. (2018) reported that the CP content of the oats-vetch mixture, oats-pea mixture was higher than the oat grown alone, while it was lower than legume monocrop pea and vetch. Research has shown that oats grown with peas can provide excellent tonnage and high-quality forage, generally increased crude protein (CP) by 2 to 4 percentage units (Owens, Nleya & Jeranyama, 2007). In the present study, we obtained a lower nutritive value of the mixtures that might be due to a poor contribution of legumes in total dry matter per plot. It can further be hypothesized that the forage mixtures improve the relationship between DM yield and nutritive value, making it possible to increase DM yield with no negative effect on the nutritive value. In field crop production, it has been established that legume-cereal intercrops may produce higher grain and protein yields as compared to the respective cereal sole crops (Jensen, 1996; Hauggaard-Nielsen et al., 2001a; Lauk & Lauk, 2005) and show greater yield stability across years than when growing legumes and cereals as sole crops (Willey, 1979; Ofori & Stern, 1987). Legume sole crops can be grown under organic farming conditions but they have some disadvantages compared to legume-cereal intercrops. Sole crops of common vetch and pea varieties may often lodge heavily, and this could be prevented by mixed cropping as such trend could also be expected in the present study.

The crude fiber content of mixture Netra-vetch mixture was higher than Netra-pea mixture. This result is similar to the findings of (Devkota et al 2015).The major reason might be due to the increased fiber content with prolonged growing period and higher fiber content in cereal oat and legume vetch. It is also observed that the fiber content of oat-legume mixture was higher than monoculture pea and vetch at all harvests. This may be due to the major contribution of oats to the fiber content of mixtures.

Total Ash

The ash content of oat-legume forages was generally higher than that of the monoculture pea and vetch at all harvests (see table 4). The present study results for total ash were similar to the findings of (Assefa & Ledin, 2001), where the oats-vetch mixture had higher ash content than vetch alone. In contrast, it was found that the ash content of pea and vetch was generally higher than that of oat-legume mixture at all harvests (Kaiser, Dear & Morris, 2007). Intercropping grasseswith legumes can improve the forage quality in terms of the ash content of the mixture than grasses alone. The ash content of the forages was found constant from the first harvest to the second harvest in grass-legume mixture and legume monoculture respectively; however, there was an increase in ash content in the 3rdharvest. The increase in total ash content might be due to slight rainfall at3rd harvest as soil nutrients solubility would be expected more in moist soil due to rainfall.

CONCLUSION

This study results revealed that oats-legume mixture had the potential for herbage productivity in abandoned lands with minimum tillage, and are likely to play a crucial role in providing quality and quantity feed for livestock enterprises as well. Oat-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, improving 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 mixed cropping 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, but needs series of experiments for future recommendations.

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Abbreviations

DM: Dry matter; CP: Crude Protein; CF: Crude Fiber; EE: Ether Extract; TA: Total ash; Ht: harvesting time; Fm: Forage mix, DMRT: Duncan`s Multiple Range Test

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