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DRY MATTER YIELD AND FORAGE QUALITY OF OAT, BARLEY AND CANOLA MIXTURE

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This study was carried out to assess the improvement in forage yield and quality of winter non-legume mixtures. For this purpose oat was intercropped with barley and canola under seeding ratios of 75:25, 50:50 and 25:75% for oat: barley/canola along with sole crops. Harvesting was done at the time of 50% heading of oat. Results revealed that sole oat produced maximum dry matter yield during both the years. None of the mixtures over yielded the respective sole crop, however the oat: barley mixture at 75:25% and oat: canola mixture at seeding ratio of 50:50% were similar to sole oat. Canola alone produced the highest crude protein (CP) yield, lowest neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents. Oat mixtures with canola have higher values for relative forage values (RFV) of the forage suggesting their better quality over oat: barley mixture. Therefore, it is suggested that to have higher dry matter yield of better quality from oat: canola mixture, ratio should be 50:50 and if oat is to mix with barley ratio should be 75:25%.
Keywords: Acid detergent fiber, dry matter, neutral detergent fiber, oat mixture, relative forage value

INTRODUCTION

Mixture sowing is a low cost technology for sustainable crop production in low input agricultural system. Higher yield in intercropping is due to efficient use of nutrients (Vandermeer, 1989; Liebman and Dyck, 1993), improved nutrient recycling (Russell, 2002), restricted nutrient leaching losses (Hauggaard-Nielsen *et al*., 2003; Ahmed *et al*., 2012) and suppression of pests and weeds (Hauggaard-Nielsen *et al*., 2001). Most commonly employed intercropping system is to mix the legume crop with non-legume to exploit the legume's potential to fix environmental nitrogen. However, the benefits from intercropping are not limited to legume inclusion in mixture. Mix sowing of two or more non-legume crops may culminate yield benefits which may rise due to structural, phenological, physiological and genetic diversity within intercrops that result in beneficial interactions among crops and between crops and environment (Kiaer *et al*., 2009; Atis *et al*., 2012). These diversities result in exploitation of growth resources at different time and space scale. In Pakistan intercropping has yet not been exploited for its reported advantages. Especially importance of mix sowing in forage production is neglected. The studies that have been conducted are mainly limited to cereal-legume combinations that resulted in improved forage yield and nutritional value.

Oat (*Avena sativa* L.) is widely grown in Pakistan under a vast range of climatic conditions. Farmers mix it with Egyptian clover to improve forage productivity. Barley (*Hordeum vulgare* L.) is another winter crop mainly grown for grain purpose in Pakistan. Certain researchers found that barley produce better quality forage than oat in terms of crude protein contents, ADF and NDF% (Ross *et al*., 2004; Todd and Spanner, 2003; Juskiw *et al*., 2000). Hence, its mix sowing with oat may improve the quality of forage.

Similarly, in addition to oil production the leaves and stem of brassica species provide high quality forage as it contains low fibre contents (13-26% ADF and 14-32% NDF) (Westwood and Mulcock, 2012), high protein contents as a percentage of dry matter; 15-25% in leaves and 8-15% in roots (Nichol *et al*., 2003) and dry matter has high metabolisable energy ranging from 11.5 to 14.5 MJ kg^{-1} (Barry *et al*., 1985). The DM% is usually low in *Brassica* but still it can produce higher DM yield than cereals (Rao and Horn, 1986). Presence of higher values of glucosinolates (sulphur containing glycosides) was the main hindrance in the use of rapeseed for livestock food. However, in canola the concentration of glucosinolates is minimum. Canola can produce quantity of forage with excellent quality (Ayres and Clements, 2002). Mixing of the seed of canola with oat may be a potential option to increase overall productivity of the fodder production system.

Beneficial effects of mixtures vary with varying proportion of the components in the mixture (Yilmaz *et al*., 2008) as the competitive ability of the crops depend on population (Baker, 1981). Increasing the seed proportion of an intercrop in mixture delays its maturity and increases the dry matter percentage (Juskiw *et al*., 2000; Alemu *et al*., 2007).

However, a very little information, especially in Pakistan, is available on the optimal seeding ratios of oat, barley and canola in binary mixtures for maximizing forage yield.
Therefore, this study was planned with the objective to evaluate the forage production potential of mixed sowing of oat with barley and canola at different seeding ratios.

MATERIALS AND METHODS

***Site and soil*:** The research was carried out at the Agronomic Research Area, University of Agriculture, Faisalabad during the winter season of 2010-11 and 2011-12. The soil of the research area was sandy clay loam in texture with 63.6% sand, 19.3% silt and 17.1% clay contents. Chemical analysis of soil revealed that soil was alkaline in nature having 7.8 and 1.53dsm^{-2} pH and electric conductivity, respectively. It was low in fertility with organic matter (0.73%), nitrogen (0.039%), available P (6.6 ppm) and available K (131 ppm). Weather data during the experimental period is given in Table 1.

Table 1. Average temperature and total rainfall per month during experiment period

Month	Rainfall (mm)		Temperature (°C)	
	2010-11	2011-12	2010-11	2011-12
October	00.0	00.4	26.3	24.7
November	00.0	00.0	18.8	20.5
December	01.0	00.0	13.3	12.5
January	00.0	3.80	10.1	10.2
February	20.6	08.0	14.4	11.5
March	06.8	1.50	19.6	18.8
April	20.9	10.5	24.8	25.3

***Treatments and crop husbandry*:** During the first year rotavator was used to incorporate the stubbles of previously sown pearl millet crops. A fine seedbed was prepared by employing three cultivations followed by two planking during both the years. Mixture combinations were managed using replacement series with seeding ratios of oat:barley/canola to be 100:0, 0:100, 75:25, 50:50 and 25:75. Seeding rates used for oat was 75 kg ha^{-1} while for barley and canola seed rates were 100 kg ha^{-1} and 12 kg ha^{-1}, respectively. Treatments were arranged in randomized complete block design (RCBD) with net plot size of 3m × 6m in three replicates. Oat was sown at 30cm spaced rows while barley and canola were sown between two consecutive rows of oat. Sowing was done with single row hand drill. Three irrigations each of 3 acre inches were applied after 35, 60 and 85 days of sowing. Nitrogenous and phosphoric fertilizers were applied at the rate of 60-80 kg ha^{-1}. Full dose of phosphorus in the form of diammonium phosphate (DAP) was applied at sowing while nitrogen was given in the form of urea in two splits, i.e. half at sowing and half with first irrigation.

***Harvesting and data recording*:** At the time of 50% heading of oat, each plot was harvested using hand sickle and intercrops were separated and weighed to have green forage weight. A 500 grams sample of chopped forage was kept in an oven at 65°C till constant dry weight. Crude protein was obtained by multiplying the nitrogen % (determined by Kjeldahl Flask method) by 6.25 (AOAC, 1990). Crude protein concentrations were multiplied with respective DM to have CP yield. Neutral detergent fiber (NDF) and acid detergent fibers (ADF) were calculated by procedure proposed by Goering and Van Soest (1970).
Relative feed value is an index which is used to rank the fodders according to their potential digestible dry matter intake and helps to allocate these forages to the proper livestock class (Table 1). This index ranks forages on bases NDF and ADF% as compared to full bloom alfalfa that has the RFV of 100. It is calculated from digestible dry matter (DDM) and dry matter intake (DMI) where DDM is the measure of total digestibility of the feed while DMI is the estimate of the feed an animal will consume as % of its body weight. Calculations were adapted from Aydin *et al*. (2010)

DDM % of DM = 88.9 – 0.779 × (ADF % of DM)
DMI % of Body weight = 120/(NDF % of DM)
RFV = DMI × DDM/1.29

Table 2. Index of forage classification (Hay Market Task Force of American Forage and Grassland Council)

Quality standard	RFV
Prime	>151
1(premium)	151-125
2(Good)	124-103
3(Fair)	102-87
4(poor)	86-75
5(Reject)	< 75

***Statistical analysis*:** Analysis of variance for dry matter yield and quality parameters was done to assess the significance of treatments and $LSD_{0.05\%}$ test was used to compare the treatment means (Steel and Torrie, 1960).

RESULTS

***Dry matter yield (t ha^{-1})*:** At the time of harvesting i.e. at 50% oat heading, all barley plants had emerged heads during both years which implies that barley heading stage reached earlier than oat (visual observation). Year effect was not significant on dry matter yield (Table 3). Among the monoculture, oat produced the highest dry matter yield while canola ranked second. However, dry matter yield from sole barley was 91.26% and 85.71% of sole canola and oat, respectively. During both the years, no mixture resulted in clear dry matter yield advantage than sole crops. Out of 12 mixtures (combined of both years) only 2 mixtures produced

Table 3. Dry matter and crude protein yield (t ha^{-1}) of oat: barley and oat: canola mixtures under different seeding proportions.

Seed proportions	DM yields (t ha^{-1})			CP yields (t ha^{-1})		
	2010-11	2011-12	Mean	2010-11	2011-12	Mean
S_1 (oat alone)	17.21abc	16.93a	17.07 a	1.74d	1.69c	1.71 de
S_2 (barley alone)	15.20cd	14.05cd	14.63 e	1.68de	1.57cd	1.64 de
S_3 (canola alone)	17.04abc	14.99abc	16.02 bc	2.93a	2.51a	2.68 a
S_4 (oat+barley 75:25)	17.30ab	16.91a	17.11 a	1.82d	1.76c	1.77 d
S_5 (oat+barley 50:50)	14.82de	14.70bcd	14.76 de	1.60de	1.57cd	1.59 e
S_6 (oat+barely 25:75)	13.11e	12.91d	13.01 f	1.45f	1.35f	1.41 f
S_7 (oat+canola 75:25)	15.96abcd	15.37abc	15.66 cd	2.13c	2.08b	2.10 c
S_8 (oat+canola 50:50)	17.55a	16.15ab	16.85 ab	2.51b	2.29ab	2.41 b
S_9 (oat+canola 25:75)	15.44bcd	14.52bcd	14.98 de	2.44b	2.20b	2.32 b
LSD (0.05%)	2.011	2.067	0.957	0.284	0.291	0.158

The means with the same letter within a column were not significantly different at p= 0.05 level

statistically higher dry matter yield than at least one of corresponding intercrop. The minimum dry matter yield in both years was observed from 25:75% oat: barley mixture.

In the oat: barley mixtures dry matter yield increased with increased oat proportion in sowing mixture which is reflected by the fact that on an average over years total dry matter yield of mixtures was increased from 13.0 to 17.11 t ha^{-1} when oat proportion in mixture was raised from 25 to 75%, respectively.This indicates the oat dominance in dry matter production in said mixtures. Dry matter yields of oat: canola mixtures were higher than oat: barley mixtures at 50:50 and 25:75% seeding ratio. However, at 75:25% seeding ratio, oat: barley mixture resulted higher DM yield but difference was not significant.

***Crude protein*:** Crude protein yield is a measure that relates CP concentration to the dry matter yield per unit area and gives a better estimate of total CP available in the season. Year effect on crude protein production was not significant (Table 3). However crude protein yield was influenced significantly by seed proportions of intercrops during both years. Crude protein yield was maximum from monoculture canola during both the years than all other treatments; however, during second year it did not differ significantly from 50:50% oat: canola mixture. Oat and barley alone produced statistically similar CP yields during both the years. The mixture with 25:75% oat: barley seed proportion with CP yield of 1.45 t ha^{-1} during first year and 1.35 t ha^{-1} during second year was the lowest CP yielder mixture. Generally, oat mixtures with canola under all seeding ratios produced higher crude protein yields than oat: barley mixtures. On an average over years, at seeding proportions of 25:75, 50:50 and 75:25%, oat:canola mixture produced 65.71, 50.94 and 17.78%, respectively, higher CP yield than oat: barley mixture. The crude protein yield in oat: canola mixture increased when canola proportion in mixture was increased from 25 to 50% but slightly decreased when canola seed proportion was increased from 50 to 75% in both years of study.

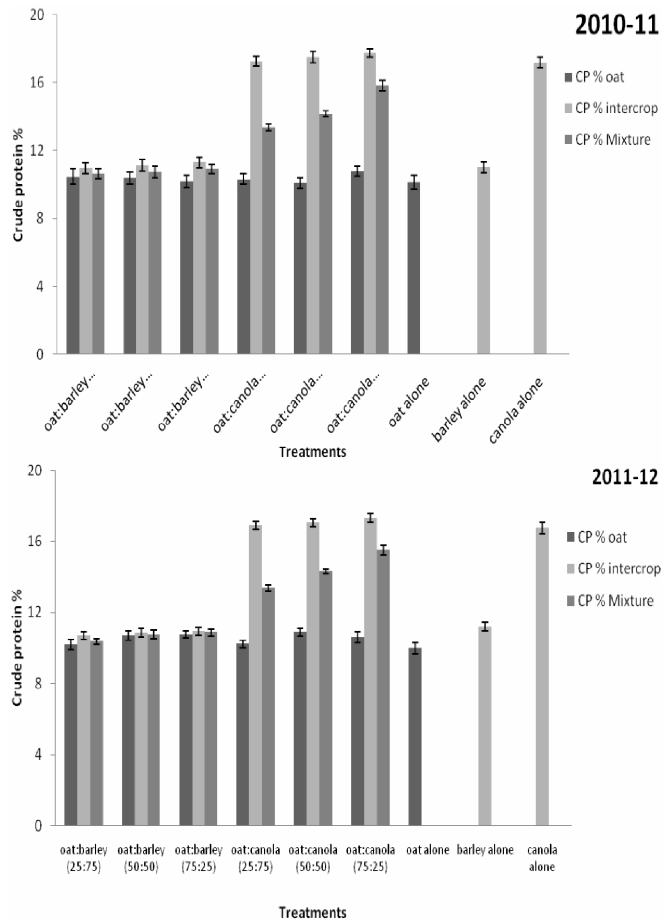

Figure 1. Crude protein concentration (CP %) of individual intercrops (oat, barley and canola) and binary mixtures under different seeding ratios.

Data regarding crude protein concentration is represented in Figure 1. Crude protein concentrations were maximum in canola during both years (17.16 and 16.74% during first and second year, respectively). Crude protein concentrations of barley (11.02 and 11.19%) was far less than canola but were slightly higher than oat. Within the mixtures, crude protein concentrations of each intercrop increased with its decreased proportion in mixture. On average over years, oat canola mixture at seeding ratio of 25:75, 50:50 and 75:25% produced 13.36, 14.21 and 15.64 % CP, respectively, while oat:barley that produced 10.48, 10.77 and 10.88 % CP of dry matter. Impact of canola in raising the CP concentrations of mixtures was more prominent than barley due to higher canola CP concentrations (Fig. 1).

***Neutral detergent fiber and acid detergent fiber concentrations*:** Growing season did not affect the treatments for NDF concentrations significantly (Table 4). Oat in monoculture gave highest NDF% during both the years producing 55.21 and 56.04% of dry matter in first and second year, respectively, while canola alone produced significantly lowest NDF% than all other treatments in both years. All the mixtures produced statistically lower NDF% than cereals (oat and barley) during both years except oat and barley in 25:75% seed proportion where it produced NDF% similar to barley alone during second year. Within the oat: barley mixtures, NDF concentrations slightly decreased with increased proportion of barley in mixture. In the oat: canola mixture, increase in the proportion of canola significantly decreased the NDF%. Hence the lowest NDF% among the mixtures was observed where canola proportion in mixture was 75%.

Further perusal of the Table 4 indicates that oat mixtures with canola produced significantly lower NDF concentrations than oat: barley mixtures at each seeding ratios. While comparing the role of barley and canola in lowering the NDF% of mixture, canola was more prominent than barley as the seeding ratio of 75:25, 50:50 and 25:75% oat: canola mixture produced (averaged over years) 19.92, 23.25 and 31.11% less NDF % than oat: barley mixtures (Fig. 2).

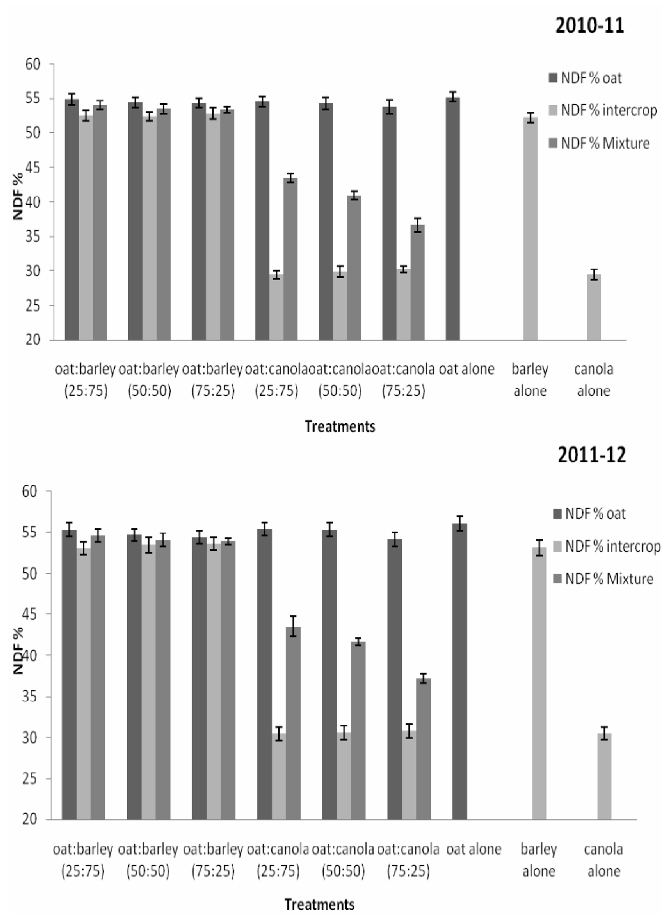

Figure 2. Neutral detergent fiber concentrations (NDF %) of individual intercrops (oat, barley and canola) and binary mixtures under different seeding proportions.

The concentrations of acid detergent fibers were not affected by growing season (Table 4). Among all treatments oat and canola alone produced statistically maximum and minimum ADF%, respectively. All the mixtures produced ADF concentrations intermediate to oat and canola monocultures. Concentrations of ADF in mixtures decreased with increased share of barley/canola in sowing mixture. On average over years, ADF % of oat: barley mixtures at 75:25, 50:50 and 25:75% were 36.68, 35.85 and 35.18% of dry matter, while of oat: canola concentrations were 30.45, 29.02 and 25.90% of dry matter. Within the mixtures oat: canola produced 16.96, 19.14 and 26.37% lower ADF% than oat: barley mixtures at 75:25, 50:50 and 25:75% seeding ratio, respectively. Generally increase in the seeding ratio of barley or canola in mixture, significantly decreased the ADF% (Fig. 3).

Table 4. Neutral detergent fiber (%), acid detergent fiber (%) and relative feed value of oat: barley and oat: canola mixtures under different seeding proportions.

Seed proportions	NDF %			ADF %		
	2010-11	2011-12	Means	2010-11	2011-12	Means
S_1 (oat alone)	55.21a	56.04a	55.63 a	38.94a	38.18a	37.78 a
S_2 (barley alone)	52.23c	53.17c	52.57 c	33.28d	33.79d	33.49 d
S_3 (canola alone)	29.46g	30.47g	29.88 g	20.38i	21.23i	20.81 h
S_4 (oat+barley 75:25)	53.99b	54.62b	54.50 b	36.34b	37.02b	36.61 b
S_5 (oat+barley 50:50)	53.48b	54.09b	53.85 b	35.46c	36.24c	35.90 bc
S_6 (oat+barely 25:75)	53.34b	53.88bc	53.60 b	34.84d	35.51c	35.17 c
S_7 (oat+canola 75:25)	43.46d	43.53d	43.58 d	30.43f	30.49 e	30.45 e
S_8 (oat+canola 50:50)	40.92e	41.65e	41.50 e	28.65g	29.33 f	29.02 f
S_9 (oat+canola 25:75)	36.68f	37.19f	37.00 f	25.58h	26.22h	25.90 g
LSD (0.05%)	0.889	0.454	0.9187	0.511	0.757	1.090

The means with the same letter within the column were not significantly different at p= 0.05 level

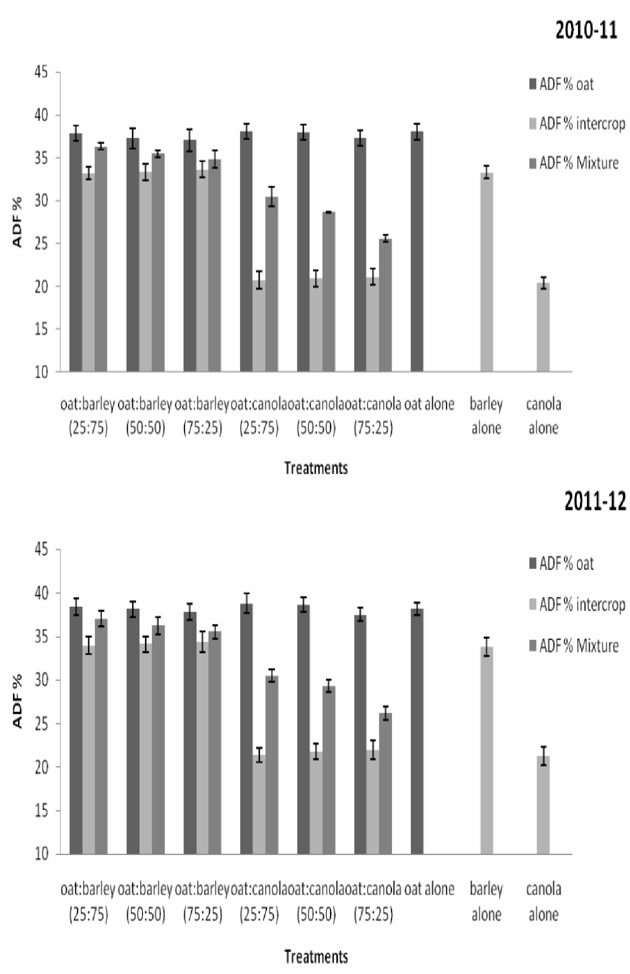

Figure 3. Acid detergent fiber concentrations (ADF %) of individual intercrops (oat, barley and canola) and binary mixtures under different seeding proportions.

***Relative forage value*:** The RFV more than 151 was recorded from canola alone and oat: canola mixture at 25:75 seeding ratio. However, oat: canola mixtures at 50:50 and 75:25 seeding ratio also gave RFV near to 151. All other forages (alone and in mixture) with respect to RFV can be categorized as fair or good (Table 5). It is further evident that RFV of oat: canola mixtures were higher than oat: barley mixtures.

Table 5. Relative feed value of mixed forage of oat with barley and canola

Seed proportions	Relative feed value		
	2010-11	2011-12	Mean
S_1 (oat alone)	100.74	98.22	99.48
S_2 (barley alone)	112.52	109.84	111.18
S_3 (canola alone)	230.70	222.14	226.42
S_4 (oat+barley 75:25)	104.08	102.07	103.08
S_5 (oat+barley 50:50)	106.55	104.03	105.29
S_6 (oat+barely 25:75)	107.78	105.73	106.75
S_7 (oat+canola 75:25)	139.59	138.84	139.22
S_8 (oat+canola 50:50)	150.15	147.12	148.64
S_9 (oat+canola 25:75)	174.58	171.21	172.90

DISCUSSION

Earliness of booting and subsequent stages in barley than oat observed in our study is in line with the result of Todd and Spaner (2003) and Ross *et al*. (2004) who reported that barley matured 4 and 7-8 days earlier than oat. This difference in phenological events of both crops in mixture is desirable as it reduces the extent of competition and provides resource complementation. Similar to our study, Kara *et al*. (2010), Aesen *et al*. (2004) and Walker *et al*. (1990) did not found clear yield advantage from oat/barley/triticale, barley/fall rye/ryegrass and wheat/ryegrass mixtures, respectively as mixture yield was intermediate to both intercrops. However, Kaut *et al*. (2008) found upto 1 t ha^{-1}more DM from wheat-oat and wheat-barley mixture than mono cropping. Yield advantage in intercropping is expected if interspecific competition is less intense than intraspecific competition (Neumann *et al*., 2009;

Lithourgidis *et al*., 2011). Oat and barley belonging to same family, posed interspecific competition to each other resulting no clear yield advantage. However, at 50:50 and 75:25% oat: canola and oat: barley seeding ratios, yields were higher than at least one of the intercrop in sole sowing (Table 3). Similar trend was observed by Kaczmarek *et al*. (2010) in his study with oat, barley and wheat binary mixtures. Of the three species, oat alone yielded higher DM yield than barley and canola alone (Table 3). Jedel and Salmon (1994) have also mentioned highest dry matter yields from oat alone than barley and triticale sole crops and mixtures. At higher oat proportion in oat: barley mixture (S_4), yield was more likely equal to highest yielder treatment (oat alone) which implies that oat provided more yield stability to mixtures though clear yield advantage was not obtained.

All the mixtures yielded higher protein contents than oat alone. Results are in agreement with previously studies of Szumigalski and Acker (2006) and Thompson *et al*. (1992) who have reported higher protein contents from wheat-canola and barley-annual rye grass mixtures from their corresponding sole crops, respectively. These findings suggest that CP improvement in mixtures can be done not only by legume inclusion in mixture besides mixtures of non legume species may also serve the purpose of forage quality improvement and this may be attributed to diversity in onset of phenological events and differential requirement of resources by the species. Higher crude protein concentrations in canola has been confirmed by Banuelos *et al*. (1992) who have reported more than 16% CP concentration in canola forage. According to Nichol *et al*. (2003) forage *Brassica* contain 15 to 25 % CP in leaves and 8 to 15% in roots dry matter and values found in this study falls well between this range. Fibrous contents of canola were well below than other species and our results are supported by the conclusion of Neely *et al.* (2009) that found very low fiber contents in canola forage and stressed on treating it as concentrate rather than fodder. The low level of fibres in canola implies the feeding of animal by supplemental roughage to compensate fibres deficiency (Bartholomew and Underwood, 2007). Similarly superiority of barley in terms of crude protein, NDF % and ADF % over oat alone has already been established by Hoffmann *et al*. (2008), Todd and Spanner (2003) and Juskiw *et al*. (2000) in their studies. Improvement in forage quality with the increased proportion of barley/canola in mixture was due to the better quality of barley and canola than oat in terms of CP, NDF and ADF%. Relative feed value (RFV) index is used to predict the intake and energy value of the forage. Hence it is based on the laboratory values of NDF% and ADF% of the feed which were lower for canola. Therefore canola in monoculture and mixture with oat has higher RFV values than other monocultures and mixtures. Although there is not direct relation between RFV and CP however forages with higher RFV values presumably have higher CP contents due to the inverse relation between CP and NDF or ADF%. This proposed principle well implies to our studies i.e. mixtures with higher RFV values have higher CP contents.

***Conclusion*:** It can be concluded from the present study that oat: canola mixtures produced better quality forage than oat: barley mixture. However low values of NDF% and ADF% in canola restricts its use as single forage and its mixture with oat optimized the NDF and ADF concentrations of mixtures with good CP yield. Hence a mixture of oat with canola with 50:50% seeding ratio established itself an excellent choice for famers to have good quality forage.

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