Acta fytotechn zootechn, 25, 2022(4): 294–302
http://www.acta.fapz.uniag.sk

Original Paper

Forage yield and quality of vetch-triticale and pea-triticale mixtures under Moroccan conditions

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Article Details: Received: 2022-05-30 | Accepted: 2022-07-07 | Available online: 2022-12-31

https://doi.org/10.15414/afz.2022.25.04.294-302

In order to investigate the forage yield and quality of vetch-triticale and pea-triticale intercrops, two years study was carried out at two locations under rainfed Moroccan conditions, considering three seeding ratios (25 : 75, 50 : 50 and 75 : 25). Results showed that intercrops yielded 46 and 52% higher than vetch and pea monocrops, while they produced 16 and 24% lower than sole triticale. Vetch-triticale intercrops out-yielded pea-triticale mixture by 11% in both locations. Within legume-triticale intercrops, forage yield increased when vetch and pea represented 25 and 50% of seeding ratios; and decreased when the legume ratio increased to 75%. The relative yield of individual species and mixtures increased when the legume ratio increased at sowing. Vetch-triticale intercrops had conflictual relationships at Sidi ElAydi (SEA) location, while pea-triticale intercrops at 50 and 75% of legume ratios, developed beneficial relations at both locations. Furthermore, intercrops affected positively forage quality at higher legumes ratios. Protein yield from vetch-triticale mixtures was significantly higher than that of pea-triticale intercrops. It was increased by 43 and 12% respectively compared to sole triticale. (Neutral detergent fiber (NDF), Acid detergent fiber (ADF) and Acid detergent lignin (ADL) decreased when legumes proportions increased in the harvested forage. A similar trend was noticed for digestibility, dry matter intake (DMI), total digestible nutrients (TDN) and relative feed value (RFV). All of these quality parameters were improved when legume ratios were beyond 25%.

Keywords: legumes-triticale intercrops, triticale, vetch, pea, forage quality

1 Introduction

Common vetch and fodder pea are the main forage legumes commonly used in rainfed areas of Morocco. These crops, even low yielding, particularly in low rainfall areas, improve the forage quality through their high protein content. Besides, annual small grain cereals such as barley, oats and triticale are commonly used as forage crops. They provide a large amount of forage, but usually have a low nutritive value that does not meet the needs of livestock due to protein deficiency. Thus, an increased interest has been devoted to cereal-legumes intercrops to increase productivity and promote yielded forage quality (Gebrehiwot et al., 2009). As the intercropping system is based on the complementarity between the species used in the mixture, the choice of the adequate companions is crucial for the success of the whole system (Bingol et al., 2007; Lithourgidis et al., 2006). Within cereal-legume intercrops, the cereal ensures a structural role as a support for legumes growth. This might facilitate mechanical harvest and prevent post-harvest losses and heavy lodge; whereas, legumes improve forage protein content and digestibility. Legumes provide biological nitrogen to cover the cereal requirement of nitrogen fertilization (Fustec, 2010) and a valuable mineral complement in the form of calcium and magnesium. Moreover, many studies have shown that cereal-legume mixtures cropping might allow agronomic, nutritional and economic advantages than sole crops (Bedoussac,

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2009). The intercropping system improves the efficiency of water and nutrient uptake (Andersen et al., 2007; Dhima et al., 2007; Launay et al., 2009), particularly the nitrogen use in agroecosystems with a low N availability (Bedoussac, 2009). Intercrops reduce weed infestation (Hauggaard-Nielsen and Jensein, 2001), plant diseases and pests occurrence leading to social benefits by increasing incomes (Onduru and Du Preez, 2007). In addition, intercropping systems involve the integration of crops in more efficient use of space and labour to promote soil conservation (Vasilakoglou et al., 2005). Otherwise, the cereal-legume intercropping system is considered as an easy and effective way to increase yield stability and nutritive equilibrium of the forage, mainly when the mixture optimal ratios are provided according to the genotype and the environment conditions (Lithourgidis et al., 2006).

Among cereals, *Avena sativa* L. (oats), *Hordeum vulgare* L. (barley) and *Triticum aestivum* L. (wheat) are the most suitable cereals for mixtures with legumes, mainly *Pisum avens* L. (pea) and *Vicia sativa* L. (common vetch) (Lithourgidis et al., 2006; Bingol et al., 2007). The forage yield and quality of the mixture are both affected by the choice of the used legume species and the cropping environments, since peas and vetch potential depend on the soil drained capacity. Hauggaard-Nielsen and Jensen (2001) reported an adding value of relative yield and protein content of intercropped barley with pea compared to recorded values of sole crops leading to a crude protein yield increase. Moreover, the yield of spring barley-pea intercrop reached the maximum without nitrogen supply. However, many studies showed the interest of triticale as an alternative cereal for mixtures with common vetch (Lithourgidis et al., 2006) and pea. Triticale is characterized by fast and early growth, high tolerance to diseases and drought. Yield performance and quality improvement in mixture with triticale depend mainly on site yield potential, seeding ratios and harvest stage. According to Carnide et al. (1998), the best compromise between yield and quality is usually obtained overall at the boot stage of the cereal and at the flowering stage of the legume species. Seeding ratios of triticale-pea mixture were correlated with forage quality components when mixtures of triticale contained at least 60% of pea and the mixture had higher dry matter yield when harvested at milk stages of the triticale. Regarding mixtures with barley and oats, many studies revealed an adding value of triticale-legumes mixtures in yield and protein content which is related to the higher proportion of legumes in the harvested forage (Yucel and Avci, 2009, Eskandari et al., 2009). Thus, the intercropping system based on triticale in a mixture with vetch or peas revealed a promising system to produce high-yielding and quality forage. However, forage yield and nutritive quality of triticale-legume mixtures are still affected by the used legume species, the technical management and the environment. Thus, the objective of the present study was to assess the effects of different seeding ratios on forage yield, the quality and the legume contribution in the harvested forage of common vetch-triticale and fodder pea-triticale mixtures under rainfed Moroccan conditions.

2 Material and methods

Field experiments were conducted during two growing seasons 2013/2014 and 2014/2015, at two experimental stations of INRA in semi-arid regions of Morocco, located at El Koudia (ELK) (34° 3′ N, 6° 46′ W) and Sidi El Aydi (SEA) (33° 10′ N, 7° 645 W), under rainfall conditions. The soil was slightly acidic (pH 5.9) and sandy loam at ELK and clay loam in SEA. The annual rainfall was 310 mm in 2013/14 and 522 mm in 2014/15 at ELK and 232 mm and 292 mm at SEA location respectively (Figure 1a & 1b).

Both soils were without depth limitation for root growth and were fertilized using 28 kg/ha of nitrogen (N), 56 kg/ha of phosphorus (P) and 28 kg/ha of potassium (K) at sowing. About 40 kg/ha of nitrogen (N) was provided at tillering stage for triticale.

Vetch (*Vicia sativa* L., 'Nawal', Pea (*Pisum avens* L., 'Naïma' and hexaploid Triticale (Triticosecale W., 'Juanillo' were tested in pure stands as sole crops and as intercrops of triticale with vetch and with pea legumes in three seeding ratios (25 : 75, 50 : 50 and 75 : 25) based on sown seeds number. Total plants density was 250 seeds/m² at sowing. Sowing was carried out manually around mid-November for both locations and growing seasons, on prepared seedbed cropped previously with lupine and oats at ELK and vetch and wheat in SEA respectively for the two growing seasons. Seeds of intercrops were mixed together before sowing. Natural nodulation occurred since soils had native rhizobium.

The field experiment was designed in a randomized complete block with four replications. Each plot had 6 rows of 6 m length and row spacing was 0.2 m.

Sole crops and mixtures were clipped at ground level when both legumes (vetch and pea) reached the flowering stage (more than 50% of flowering) and lower pods started setting. Green forage samples were taken from 4 m² area from central rows.

Harvested forage was sorted out manually into legumes (pea and vetch) and triticale to determine the weight of the mixture's components. The contribution of legumes to harvested forage (LCH) was estimated by the part of legumes within total harvested forage expressed in percent. Samples of 500 g from each component were dried at 70ºC for 48 hours to determine the dry matter yield. The contribution of legumes was expressed as the percentage of the mixture dry matter yield in each plot.

To assess the advantages and disadvantages of mixed stands compared to pure stands, relative yields of the three species (vetch, pea and triticale) were calculated as a ratio of yields in the mixture to their yield as sole crops (eq. 1). Total Relative Yield (RYT) was calculated as the sum of partial relative yields of mixture species (eq. 2). According to Caballero et al. (1995), the RYT value greater than the unity (1), indicates that intercropping favoured the growth and yield of the species within the mixture. Conversely, when the RYT value is less than 1, implies that the growth and yield of the species were negatively affected by intercropping.

$$\text{relative yield (RY)} = \text{yield of specte in mixture/ yield of specte in pure stand} \quad (1)$$

$$\text{total relative yield (RYT)} = \text{RY triticale} + \text{RY legume} \quad (2)$$

Forage quality was assessed at harvest time. Samples of 500 g of forage dry matter from each plot were ground to pass a 1 mm screen. The quality components analyzed were total N using the Kjeldahl method (Bremner, 1965); crude protein (CP) was calculated by multiplying N content by 6.25 according to AOAC (1980). Neutral and acid detergent fiber (NDF and ADF) and acid detergent lignin (ADL) were determined using the Van Soest (1967) procedure. The total digestible nutrient (TDN) (eq. 3), digestible dry matter (DDM) (eq. 4), dry matter intake (DMI) (eq. 5) and relative feed value (RFV) (eq. 6) were estimated according to the following formulas (Horrocks and Vallentine, 1999).

$$\text{total digestible nutrient (TDN)} = (-1.291 \times \text{ADF}) + 101.35 \quad (3)$$

$$\text{digestibke dry matter (DDM)} = 88.9 - (0.779 \times \text{ADF \% DM}) \quad (4)$$

$$\text{dry matter intake (DMI)} = 120/\text{NDF\%DM} \quad (5)$$

$$\text{relative feed value (RFV)} = \text{DDM} \times \text{DMI} \times 0.775 \quad (6)$$

Generated data from agronomical and quality parameters were subjected to variance analysis (ANOVA) using GLM (General Linear Model). Treatment mean differences were separated by the least significant difference (LSD) test at the 0.05 probability level and supplemented by the Duncan test for mean comparison using SAS software (version 9.1).

2.1 Climatic conditions

A variation of climatic parameters was observed among and between the two growing seasons in both experimental sites (Figure 1a & 1b). At ELK, rainfall amount was low and irregular mainly at the early growth cycle during 2013/2014, in addition to a very wet spring.

However, rainfall amount and pattern were regular during the second growing season 2014/2015 (Figure 1a). At SEA, rainfall was regularly distributed during the first growing season; but during 2014/15, a maximum of rainfall was received just after sowing followed by a severe spring drought (Figure 1b).

3 Results and discussion

3.1 Forage yields

Analysis of variance for forage yield revealed significant differences (*P* >0.05) among sites and seeding ratios, with an interaction between seeds ratios and sites (Table 1 and 2). Whereas, no year effect and no interaction exist between seeds ratios and years were observed. So, the means values of the two growing seasons are considered for each location.

Harvested forage quantities from intercrops were intermediate between triticale and legumes sole crops yields (Table 1 and 2). Average production from intercrops exceeded that of the legumes sole crop by 54%, by 39% for common vetch-triticale and by 65% and 40% for fodder pea-triticale respectively in SEA and ELK. Conversely, yields of the intercrops were lower than sole triticale yield by 20% and 13% for common vetch-triticale and by 27% and 22% for fodder pea-triticale mixture respectively in SEA and ELK. Average mixture yields were 5.75 and 5.14 t/ha for common vetch-triticale and fodder pea-triticale respectively at ELK and of 6.74 and 6.13 t/ha respectively at SEA. Vetch-triticale mixtures yielded about 11% more than pea-triticale mixtures in the two environments. Otherwise, the mean yields of legumes conducted as sole crops were rather close among locations with a slight superiority of common vetch than fodder pea of 15% (Table 1 and 2).

Forage yield tends to decrease as triticale's proportion decreased in the mixture. Triticale-legume intercrops with common vetch or fodder pea, at seeding ratios (25 : 75 and 50 : 50) yielded comparable forage amounts in both locations. While, the increase of legumes proportion to 75% of total sown seeds resulted in a significant yield decrease except for triticale-vetch at ELK location. These results are in concordance with other findings (Kokten et al., 2009; Yucel and Avci, 2009). Many studies reported that increasing legumes ratios from 25 to 50% in cereal-

Table 1 Dry matter, legume contribution and relative yield of intercrops of common vetch and fodder pea with triticale at three sowing ratios (25 : 75, 50 : 50 and 75 : 25) and respective sole crops at El Koudia location

Crops	Seed ratios	DM (t/ha)	LCH (%)	RYtcl	RYleg	RYT
Triticale	100	6.60	–	1.00	–	1.00
25 Vetch : 75 Triticale	25 : 75	6.16	10	0.84	0.15	0.99
50 Vetch : 50 Triticale	50 : 50	5.59	29	0.60	0.39	0.99
75 Vetch : 25 Triticale	75 : 25	5.49	43	0.48	0.55	1.04
Vetch	100	4.13	100	–	1.00	1.00
25 Pea : 75 Triticale	25 : 75	5.44	25	0.61	0.38	0.99
50 Pea : 50 Triticale	50 : 50	5.36	43	0.47	0.62	1.09
75 Pea : 25 Triticale	75 : 25	4.63	72	0.19	0.92	1.11
Pea	100	3.66	100	–	1.00	1.00
Mean	5.23	–	–	–	–	–
LSD (α<0.05)	0.65	6.77	0.08	0.06	0.12	–

DM – dry matter yield (t/ha), LCH – legumes contribution at harvest (%), RYtcl – relative yield of triticale; RYLeg – relative yield of legumes, RYT – total relative yield

Table 2 Dry matter, legume contribution and relative yield of intercrops of common vetch and fodder pea with triticale at three sowing ratios (25 : 75, 50 : 50 and 75 : 25) and respective sole crops at SidiElAydi location

Crops	Seed ratios	DM (t/ha)	LCH (%)	RYtcl	RYleg	RYT
Triticale	100	8.44	0	1.00	–	1.00
25 Vetch : 75 Triticale	25 : 75	7.04	10.3	0.75	0.17	0.91
50 Vetch : 50 Triticale	50 : 50	7.17	14.1	0.73	0.23	0.96
75 Vetch : 25 Triticale	75 : 25	6.01	34.0	0.47	0.47	0.94
Vetch	100	4.37	100	–	1	1
25 Pea : 75 Triticale	25 : 75	6.45	16.2	0.64	0.29	0.93
50 Pea : 50 Triticale	50 : 50	6.54	22.2	0.60	0.40	1.00
75 Pea : 25 Triticale	75 : 25	5.41	47.0	0.34	0.68	1.02
Pea	100	3.72	100	–	1.00	1.00
Mean	6.13	–	–	–	–	–
LSD (α <0.05)	0.96	4.07	0.09	0.04	0.05	–

DM – dry matter yield (t/ha), LCH – legumes contribution at harvest (%), RYtcl – relative yield of triticale, RYLeg – relative yield of legumes, RYT – total relative yield

legume mixtures resulted in a high dry matter yield per unit area (Albayrak et al., 2004; Tuna and Orak, 2007).

3.2 Legume contribution in Forage

Intercrops seeding ratios affected legume contribution to harvested forage in the two locations. At ELK, intercropping vetch at 25% resulted in a weak share at harvest (10%), which improved when seed ratios increased to reach 43% at 75% at ELK. At SEA the share of vetch at harvested forage did not differ when increasing the seed rate from 25 to 50%. Vetch contributed by 34% within forage when the seed ratio raised to 75% (Table 2).

Forage from fodder pea was significantly higher than vetch proportions within harvested forage (Table 1). Fodder pea shares within harvested forage were close to those previously sown at ELK location, but significantly below at SEA. This result underlines the environment impact on the final proportion of legume species at harvest. Our results support those of Kokten et al. (2009).

Otherwise, fodder pea seems to be more competitive than common vetch intercropped with triticale mainly at ELK conditions. Compared to vetch, fodder pea was well established within the mixtures and had more ability to use the ELK environmental resources for its growth and development. In general, species within the mixtures undergo social relationships according to their ability to use the environmental resources. These relations are

Table 3 Statistical parameters of crude proteins content and fibers

Statistic parameters	Treatment	Site	Treat × site	Mean square	*F* value
Crude proteins (% DM)	***	***	*	20.03	20.10***
Neural detergent fiber	*	NS	NS	32.70	4.26*
Acid detergent fiber	*	NS	NS	11.10	3.02*
Acid detergent lignin	NS	NS	NS	2.13	1.13

*, **, *** significant correlation at 0.5, 0.01 and 0.001 probabilities respectively; NS – non-significant effect at P <0.05

numerous and variable through plants growing cycle, depending on environmental factors.

3.3 Relative yields

Total relative yield (RYT) values calculated from harvested forage dry weight were close to 1 (0.99) or superior than 1 for tested intercrops at ELK (Table 1) indicating that legumes and triticale's growth had neutral or beneficial sharing of environmental resources. The RYT of pea-triticale mixtures at 50P : 50T, 75P : 25T seeding ratios and vetch-triticale at 75V : 25T were 1.09, 1.11 and 1.04 showing that 9%, 11% and 4% more area would be required for a pure stand crop to reach the yield from an intercropping system. However, in SEA location, RYT were less than 1 for all mixtures of vetch-triticale as well as 25 : 75 pea-triticale mixture. These values of RYT less than unity mean that relations of competitions prevailed during the crop growing cycle. Accordingly, there was limited advantage from intercropping over monocultures in terms of using land and environmental resources for plant growth. Pea-triticale mixtures sown at 50P : 50T and 75P : 25T at SEA showed neutral and beneficial sharing of environmental resources. The relative yield of common vetch was lower for common vetch-triticale mixtures compared to that of pea-triticale mixtures for the same seeding ratios in both locations.

3.4 Proteins content (PC) and proteins yield (PY)

Analysis of variance revealed a significant intercrop effect (P <0.01) for crude protein content within legume-triticale mixtures and sole crops (Table 4). The mean protein content scored 11.8% DM, ranged between 16.9% DM for vetch sole crop and 7.08% DM for pure stand triticale. The mean PC of vetch and of fodder pea (13.15% DM) represented respectively about three times and nearly doubled the triticale PC value. Giacomini et al. (2003) supported our finding by reporting the lowest CP in triticale monoculture compared to mixtures and legumes sole crop.

Vetch-triticale and pea-triticale mixtures exhibited intermediates CP values between their respective sole crops. In both vetch-triticale and pea-triticale mixtures, forage protein content increased as legumes seeding ratios increased in the mixture in agreement with Lithourgidis et al. (2006) study. CP contents of vetch-triticale intercrops were higher than PC of pea-triticale mixtures as shown in Table 4. The mean CP of common vetch-triticale and fodder pea-triticale mixtures were 12.2% DM and 10.6% DM respectively. Thus, mixtures based on vetch offered at least an adding value of 15% of CP.

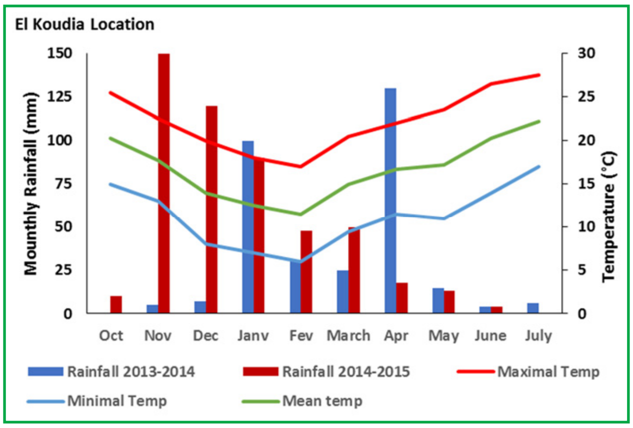

Figure 1a Monthly rainfall and mean, maximal and minimal air temperatures during the two growing seasons, from October 2013 to July 2014 and from October 2014 to July 2015 of EL Koudia experimental location

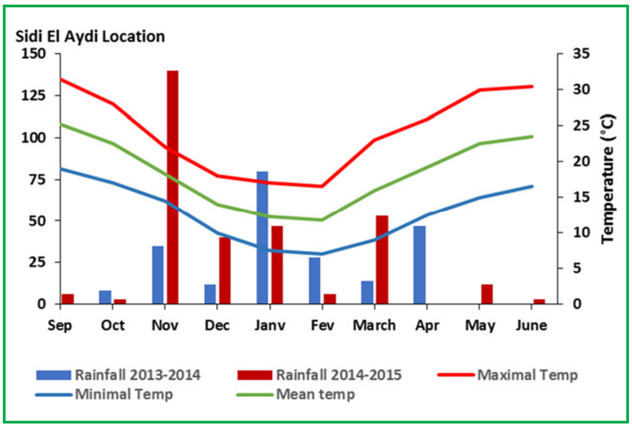

Figure 1b Monthly rainfall and mean, maximal and minimal air temperatures during the two growing seasons from October 2013 to July 2014 and from October 2014 to July 2015 of SidiElAydi experimental location

Compared to sole triticale, forage PC was improved by 79.4%, 63.8% and 39.5% for legumes-triticale mixture at 75%, 50% and 25% of legumes proportions respectively. The adding value of PC was higher for common vetch-triticale mixtures than fodder pea-triticale mixtures leading to an increased advantage of common vetch in mixture with triticale of 34%, 23% and 12% at respectively 75%, 50% and 25% of legumes ratios. Our results confirm those revealed by Lithourgidis et al. (2006), which reported that intercropping common vetch with different cereals results in crude protein enhancement in all cropping ratios.

Consequently, the intercropping legumes with triticale improved protein yields compared to triticale monocrop. Increased legume-seeding ratios affected positively intercrops protein yields as reported also by Sadeghpour et al. (2014).

Protein yields for monocrops averaged 0.53, 0.51 and 0.72 t/ha for triticale, fodder pea and vetch respectively. The mean protein yield of vetch-triticale intercrops (0.75 t/ha) was significantly higher (24%) than pea-triticale mixtures (0.57 t/ha).

Protein yields produced by vetch-triticale intercrops ranged from 0.63 to 0.76 t/ha at ELK and from 0.73 to 0.89 t/ha at SEA. Whereas, harvested protein yields from fodder pea-triticale mixture varied from 0.51 to 0.58 T/ha in ELK; and from 0.61 to 0.71 T/ha at SEA. The advantage of vetch-triticale intercrop was related to both larger production of biomass with higher protein content compared to pea-triticale mixtures. Otherwise, compared to triticale monoculture, protein yields for pea-triticale and vetch-triticale mixtures have increased by 16% and 49% at ELK and by 8% and 36.5% respectively at SEA.

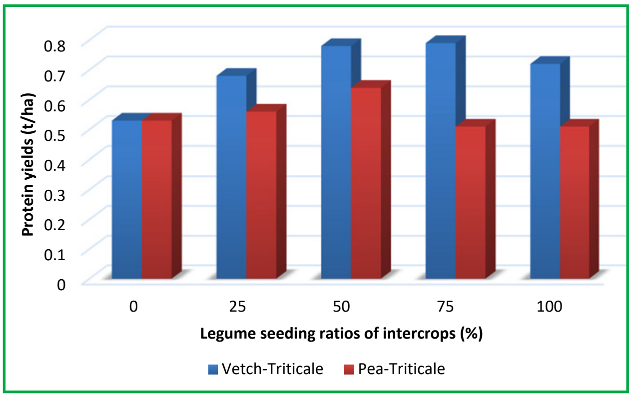

Figure 2 Mean protein yields (t/ha) of monocrops and legume-triticale intercrops at three seeding ratios

Thus, the interest in a vetch-triticale mixture is mainly in SEA environment.

The highest protein yield was recorded for 75V : 25T seeding ratios at ELK (0.76 t/ha) and 50V : 50T at SEA (0.89 t/ha). This finding might be explained in ELK location by high protein content (16% DM); an increase of vetch proportion in harvested forage (43%) and better competitiveness (RYVetch = 0.55) (Table 1). While, in SEA location, high protein yield might be explained by a high forage yield despite of a low protein content in harvested forage (11.2% DM) (Figure 2).

3.5 Constituents of the cell wall

Variance analysis revealed that legume seeding ratios within intercrops affected both NDF and ADF (P <0.01). The highest values of NDF (59 g/100 gDM), ADF (41.2 g/100 gDM) and lignin (7.03 g/100 gDM) contents were recorded for triticale sole crop (Table 4). However,

Table 4 Forage quality of triticale, vetch and pea sole crops and mixtures of vetch-triticale and pea-triticale at three seeding ratios (g/100 g dry matter)

Crop/(g/100 g DM)	Ratios	CP	NDF	ADF	ADL	DMD	DMI	TDN	RFV (%)
Triticale	100	7.08e	59.0a	41.2a	7.03a	56.8b	2,03c	48.2c	89.6c
Vetch	100	16.9a	47.0d	37.2b	6.78ab	60.0ab	2.56a	53.4b	118.8a
Pea	100	13.8b	51.4c	31.4c	5.35bc	64.5a	2.34ab	60.9a	116.8a
Vetch : Triticale	25 : 75	10.3cd	58.5a	37.0b	6.66ab	60.1ab	2.05c	53.6b	95.8b
Vetch : Triticale	50 : 50	12.4c	53.2bc	37.1b	6.01ab	60.0ab	2.26ab	53.5b	104.9ab
Vetch : Triticale	75 : 25	13.9b	52.3bc	35.6bc	5.29bc	61.2ab	2.29ab	55.4ab	108.8ab
Pea : Triticale	25 : 75	9.45d	57.7a	38.1b	6.51ab	59.3ab	2.08c	52.2bc	95.5b
Pea : Triticale	50 : 50	10.8cd	56.1ab	38.9b	5.31bc	58.6ab	2.14b	51.1bc	97.2b
Pea : Triticale	75 : 25	11.5c	53.7bc	35.6bc	4.59c	61.2ab	2.24ab	55.5ab	106.1ab
Mean		11.8 ±0.9	54.3 ±1.2	36.9 ±1.1	5.95 ±0.4	60.2 ±1.4	2.22 ±0.1	53.7 ±1.2	103.7 ±4.5

means within column followed by different letters differ significantly at P <0.05
CP – crude proteins, NDF – neural detergent fiber, ADF – acid detergent fiber, ADL – acid detergent lignin, DMD – dry matter digestibility, DMI – dry matter intake, TDN – total digestible nutrient, RFV – relative feed value

they decreased when legumes proportions increased in the harvested forage for both vetch and pea intercrops (Table 4). Similar results were reported previously by Castro et al. (2000); Yucel and Avci (2009) and Pereira-Crespo et al. (2010).

At 75% of triticale seeding ratio, triticale is widely present in harvested forage as it was more competitive (RYT less than unit). Thus, the increasing legume-seeding ratio may provide therefore better forage quality compared to sole crop triticale.

Otherwise, a detergent analysis system was developed to separate the cell soluble components (starch, protein, sugars) from fibers, which consist of cellulose, hemicellulose and lignin component. Neutral and Acid Detergent Fiber measures respectively the amount of hemicellulose, cellulose and lignin and the cellulose and lignin content in harvested forage.

The NDF and ADF are partially digestive and provide energy, while the indigestible fiber (ADL) may limit the intake. That is why nutritionists used NDF and ADF components to predict feed intake and then formulate dairy rations.

The lowest amount of lignin component was recorded for fodder pea (4.59 g/100 g DM) followed by common vetch (5.29 g/100 g DM) (Table 4). Compared to sole crop triticale, the intercropping system reduced ADL content when the legumes ratio increased from 3.6 to 14.5% in the case of vetch-triticale and from 7.4 to 24.5% for pea-triticale mixture. Accordingly, Chen et al. (2004) and Lauriault and Kirskey (2004) reported that mixtures provided better forage quality than triticale sole crops. According to our results, an intercropping system based on pea or vetch mixed with triticale might be more efficient to increase digestibility by reducing ADL amount in harvested forage supporting therefore greater milk production. This confirms the previous findings of Chen et al. (2004) and Sadeghpour et al. (2014).

3.6 Digestibility and dry matter ingestion

Digestibility and potential intake values are determined from ADF and NDF contents. Digestible dry matter (DDM) represents the extent to which forage is absorbed as it passes through an animal's digestive tract. The highest DDM was recorded for pea sole crop (64.5 g/100 g dry matter); while pure stand triticale registered, the lowest value (56.8 g/100 g dry matter). Digestible dry matter (DDM) was improved by 7.8% when legume seeding ratios were up to 50% (Table 4). These results agree with those previously found (Lithourgidis et al., 2006).

Dry matter intake (DMI) is an estimate of the relative amount of forage that an animal will voluntary intake. DMI depends essentially on the content of lignified cell walls of the forage (ADL) and on rumen-fill effect. The highest DMI was recorded for common vetch, followed by fodder pea sole crops. DMI increased as the legumes ratio in the mixture increased (Table 4). Thus, the lowest DMI was recorded for pure stand triticale and for both legumes-triticale at 25% legume ratio (Table 4). These results are in agreement with those reported by Ullah (2010) revealing that DMI of legumes is much higher than triticale and decreases in the triticale-legume mixture as legume ratio in the mixture decrease. Furthermore, available nutrients as assessed by total digestible nutrient (TDN) were maximal in fodder pea forage followed by common vetch harvest. Triticale sole crop registered a minimal value of TDN (Table 4). A significant increase of TDN was observed when the legumes ratio reached 75% within legume-triticale intercrops.

3.7 Relative feed value

The relative feed value (RFV) index integrates both digestibility and intake potential to compare forages based on energy. RFV ranged from 89.6 for sole triticale to 118.8% for vetch and pea monocrop with comparable values. Thus, vetch and pea provide about 19% more energy than mature alfalfa (RFV = 100). Intercrops RFV values were intermediate between triticale and both legumes sole crops with significant differences within intercrops and monocrops (P <0.01) (Table 4). RFV increased when the vetch or pea ratio increased up to 25%. Legumes-triticale intercrops harvested forages could be compared based on energy using RFV values. An adding value of energy was achieved when the vetch ration was above 50% in vetch-triticale mixtures and when the pea ratio was 75% in pea-triticale mixtures (Table 4). This underlines the efficiency of legumes in increasing the relative feed values when intercropped with triticale. The relative feed value (RFV) index might be useful to predict forage intake.

4 Conclusions

Intercropping legume with cereal is a sustainable approach to increase both forage yield and quality through efficient use of land and environmental resources. The present study demonstrates that intercropping of vetch and pea with triticale at three seeding ratios affect forage yield and quality parameters. Yields from intercrops were intermediate between triticale and legumes sole crops. The highest forage yield was obtained from triticale, while both legumes provided the lowest yields. Vetch-triticale intercrops yielded about 11% more than pea-triticale mixtures in both locations. Legume-triticale intercrops, at seeding ratios (25 : 75 and 50 : 50) yielded comparable forage amounts and the increase of legumes ratio to 75%

resulted in a yield decrease. Legumes shares at harvest were below those previously sown and pea contribution in yield was significantly higher than vetch. The relative yield of individual species and mixtures was affected by intercropping and it increased when the legumes ratio increased. RYT were equal or superior than 1 in El Koudia location indicating that legumes and triticale had neutral or beneficial sharing of environmental resources for their growth. However, relations of competition prevailed during the crop growing cycle for all mixtures of vetch-triticale in SidiElAydi location.

Intercrops affect positively the forage quality parameters and the highest forage quality was achieved in 75 : 25 legume triticale ratios. Vetch-triticale intercrops yielded high protein forage in the two sites. Digestibility of harvested forage from legumes-triticale intercrops was improved when legume ratios were above 25% following the increase of dry matter intake, total digestible nutrients and relative feed value.

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