AJFAND ONLINE
Volume 10 No. 10
October 2010
ISSN 1684 5374
Peer Reviewed
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

EFFECTS OF SEEDING RATES ON FORAGE YIELD AND QUALITY OF OAT (*AVENA SATIVA* L.) VETCH (*VICIA SATIVA* L.) MIXTURES UNDER IRRIGATED CONDITIONS OF MADAGASCAR

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ABSTRACT

Forage availability and quality during the dry and cool season is a major constraint to dairy development in the Highlands of Madagascar. The objective of the present study was to determine optimal seeding of oat and common vetch mixtures for increased production and quality of forage. The study was conducted under irrigated conditions in two agro-ecological zones of the Vakinankaratra region in the Highlands of Madagascar. Seed proportions studied were oat-vetch 100:0; 0:100; 50:50 and 50:75. Pure stands of oat and vetch were seeded at the rate of 100 and 60kg ha^{-1}, respectively. Standard fertilization for forage oat production was uniformly applied on each plot. Pure stands and mixtures were given two successive cuts at flag leaf stage of oat. For both sites and their average, dry matter (DM), feed unit for lactation (UFL), crude protein (CP), and protein digested in the small intestine (PDI) yields were not significantly ($p>0.05$) different among mixtures and pure stands. The highest yields were obtained from the 50:50 mixture at the first site and from the 50:75 mixture at the second site. According to the two sites' results' average, the highest DM (7.71 t ha^{-1}), UFL (6.08×10^3 units ha^{-1}), CP (1.64 t ha^{-1}) and PDI (597.1kg ha^{-1}) yields were obtained from 50:50 mixture. There were no significant differences ($p>0.05$) in forage quality characteristics except for CP and protein digested in the small intestine when rumen-fermentable nitrogen is limiting (PDIN). Mean CP concentration varied from 15.20% for pure stand of oat to 27.01% for pure stand of vetch. The highest value (178.8 g/kg DM) and the lowest value (103.5g/kg DM) in PDIN content were obtained from pure stand of oat and pure stand of vetch, respectively. Mixtures had 4.6 to 6.3% more CP content and 15.6 to 39.1% more PDIN content than pure stand of oat. Combined land equivalent ratio values exceeded unity in both mixtures which showed an advantage of intercropping over sole system in terms of the use of environmental resources. As intercropping of oat with vetch at 50:50 (50:30 kg ha^{-1}) mixture achieved maximum yield advantage and forage quality, it could be used as alternative practice of oat sole cropping for high forage and protein production in the Vakinankaratra region.

Key words: mixture, forage, quality, oat, vetch

INTRODUCTION

Small-scale dairy production is an important smallholder farming system in the Highlands of Madagascar [1]. The promotion of livestock breeding and improved management practices for zero grazing has resulted in increased ability to produce milk. However, feed availability and quality during the dry and cool season is a major constraint to the dairy development. The use of low quality crop residues as main feed resources has resulted in significant decrease in milk production and loss of body weight [2]. An alternative strategy to improve both quality and quantity of available forage is the development of grass-legume mixtures [3]. This would be likely to diminish the fall of milk production in the dry season hence stabilise the incomes of farmers and contribute to poverty reduction. Oat (*Avena sativa* L.) is a widely grown fodder plant in the Highlands of Madagascar particularly in the Vakinankaratra region where 90% of dairy farmers are found [4]. It is adapted to a wide range of soil types and altitudes and is cultivated under rain fed or irrigated conditions on riceland [5]. The present study assessed the potential of oat and vetch (*Vicia sativa* L.) mixtures for improved livestock feeding and productivity. The objective of the study was to determine the optimum seeding rates for maximum forage yield and quality improvement.

MATERIAL AND METHODS

Study areas

The study was conducted under irrigated conditions in two agro-ecological zones of the Vakinankaratra region, at 1700 m (Antsirabe) and 1500 m (Betafo) above sea level, during the dry and cool season (June-September) of 2007. The Vakinankaratra region is located in the central highlands of Madagascar between latitude 18.3° - 19 °S and longitude 46° - 47.3 °E. The area is characterised by tropical climate altitude with two main seasons, six months of dry and cool season extending from May to October and six months of rainy season extending from November to April. Rainfall declines from East to West and annual mean is 1300 mm. Soils are of three groups, humiferous dark-coloured ferralitic (andosols), hydromorphic and typical unsaturated ferralitic [6]. Soil parent material is from ancient (Antsirabe) and recent (Betafo) volcanic origin.

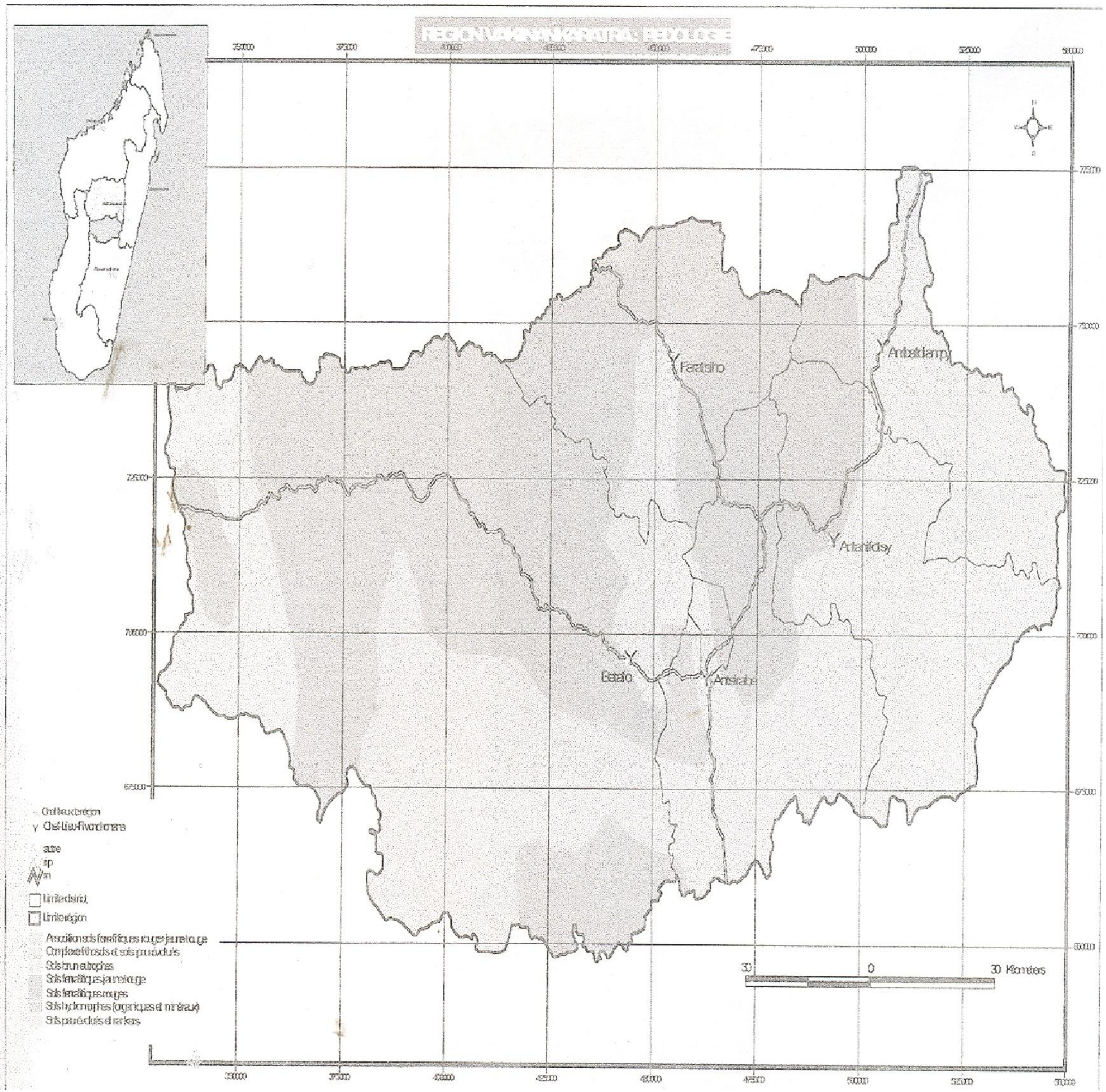

Figure 1: Map of the Vakinankaratra Region, showing the two study areas

Experimental design

The experimental design employed was a randomised complete block design with four replications. The treatments included seed proportions of oat (cv W99-153) and vetch (cv 5127D) as follows: 100:0 (100% oat), 0:100 (100% vetch), 50:50 (50% oat + 50% vetch) and 50:75 (50% oat + 75% vetch). The seed proportions were calculated on the basis of the recommended sole seed rates of 100 and 60 kg per hectare for oats and vetch, respectively. Germination test was done on seeds of both crops before sowing in order to adjust the seeding rates. The local fertilizer recommendation of 125 kg N, 66 kg P_20_5, 48 kg K_20 and15 tons of cattle manure ha^{-1} was uniformly applied on all plots. The plot size was 3 m x 3 m and the spacing between rows was 20 cm. Mixtures were established in alternate rows. Hoeing and hand weeding were conducted during establishment and subsequently, as deemed necessary.

Data collection

Fresh matter yield was estimated from harvesting herbage from 2 m x 2 m quadrat in the central rows of each plot. The harvested herbage was sub-sampled and dried to constant weight in a forced draft oven at 60° C for 72 hours. The dried composite forage samples from each treatment were milled to pass through a 1mm sieve for proximate analysis and a 2 mm sieve for rumen degradation study [7]. Forage quality was assessed in terms of energy unit effectively available to the animal (Feed Unit for Lactation, UFL), crude protein (CP), protein digested in the small intestine when rumen-fermentable nitrogen is limiting (PDIN), protein digested in the small intestine when rumen-fermentable energy is limiting (PDIE), crude fibre (CF) and total ash (TA) contents. Dry matter (DM), UFL, CP and PDI yields were then calculated. Intercropping systems were assessed on the basis of intercropping indices such as land equivalent ratio (LER), relative crowding coefficient (RCC or *K*), aggressivity (*A*), and competitive ratio (CR). Pure stands and mixtures were given two successive cuts at flag leaf stage of oat.

Chemical analysis

Concentrations of TA, CP, CF, UFL, PDIN and PDIE were determined according to the Official Methods of Analysis [7]. Crude protein content was analyzed by the Kjeldahl method. Total ash content was determined by incinerating dried samples in a muffle furnace at 550°C for six hours. The UFL, PDIN and PDIE contents were determined according to nylon bag technique.

Biological competition (potentials) functions

The land equivalent ratio (LER) was used as criterion for measuring efficiency of intercropping advantage using the resources of environment compared with mono-cropping [8]. When the value of LER is greater than one, the intercropping favours the growth and yield of the species. When LER is lower than one the intercropping negatively effects the growth and yield of crops grown in mixtures [9]. Land Equivalent Ratio (LER) was calculated by the following formula: LER= {La + Lb} La = (Yab/Yaa) Lb = (Yba/Ybb) where La and Lb are the LERs for the individual crops, Yab and Yba are the individual crop yields in intercropping and Yaa and Ybb are the individual crop yields in sole cropping [10]. Relative crowding coefficient

AJFAND ONLINE
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(RCC or K) is the measure of relative dominance of one species over the other in intercropping [11]. The K was calculated as K = (K *oat* x K *vetch*) K *oat* = {Yab Zba} / {(Yaa – Yab) Zab } K *vetch* = {Yba Zab} /{ (Ybb – Yba)Zba } Where Zab is sown proportion of oat in intercropping, Zba is sown proportion of vetch in intercropping, Yab is the yield of oat in intercropping, Yba is the yield of vetch in intercropping, Yaa is the yield of oat in monocropping and Ybb is the yield of vetch in intercopping. When the product of two coefficients (K *oat* x K *vetch*) is greater than one, there is a yield advantage, if the value of K is one there is no yield advantage and if less than one there is no yield advantage and the system has disadvantage.

Aggressivity (A) is used to determine the competitive relationship between two crops used in the mixed cropping [12]. The aggressivity was formulated as fallows: Aoat = {Yab / (Yaa x Zab)} – {Yba / (Ybb x Zba)} and Avetch = {Yba / (Ybb x Zba)} – {Yab / (Yaa x Zab)} [13]. If the value of A is zero, both crops are equally competitive. İf the value of Aoat is positive then oat is dominant over vetch. If the value is negative then oat is weak. Competitive ratio (CR) is another way to assess competition between different species. Competitive ratio gives better measure of competitive ability of the crops and is also advantageous as an index over K and A [14]. The CR simply represents the ratio of individual LERs of the component crops and takes into account the proportion of the crops in which CR *oat* (LER oat / LER *vetch*) (Zba / Zab) CR *vetch* = (LER *vetch* / LER *oat*) (Zab / Zba).

Statistical analysis

Data obtained were subjected to statistical t-test and analysis ANOVA followed by means separation according to the lowest significant difference method (LSD) ($P<0.05$) using Genstat statistical packages [15].

RESULTS

Dry matter, UFL and crude protein yields

For both sites (Antsirabe and Betafo), DM, UFL, CP and PDI yields were affected by seed proportions ($p<0.001$) (Tables 1 and 2). At the first site (Antsirabe), DM yield varied from 5.41 t ha^{-1} for pure stand of vetch to 7.64 t ha^{-1} for mixture including 50% oat and 50% vetch (50:50) (Table 1). This latter mixture produced 18.6% and 41.2% more dry matter yield than pure stand of oat and pure stand of vetch, respectively. The UFL yield varied from 4.23×10^3 units ha^{-1} for pure stand of vetch to 6.31×10^3 units ha^{-1} for 50:50 mixture (Table 1). Crude protein yield ranged from 0.89 t ha^{-1} for 50:75 mixture to 1.52 t ha^{-1} for 50:50 mixture (Table 2). The PDI yield varied from 417.46 kg ha^{-1} for pure stand of vetch to 585.12 kg ha^{-1} for 50:50 mixture (Table 2). At the second site (Betafo), The highest DM (8.62 t ha^{-1}), UFL (6.70×10^3 units ha^{-1}), CP (2,02 t ha^{-1}) yields were obtained from 50:75 mixture while the lowest DM (5.52 t ha^{-1}), UFL (4.39×10^3 units ha^{-1}), CP (0.81 t ha^{-1}) yields were obtained from pure stand of oat (Table 2). The PDI yield ranged from 468 kg ha^{-1} for pure stand of oat to 609 kg ha^{-1} for the 50:50 mixture (Table 2). According to the two site's results average, DM, UFL, CP and PDI yields were not affected by treatment ($p>0.05$) (Tables 1 and 2). The highest value (7.71 t ha^{-1}) and the lowest value (5.98 t ha^{-1}) in DM yield were

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obtained from 50:50 mixture and pure stand of oat, respectively (Table 1). Mixtures produced 24 to 28% more dry matter than pure stand of oat and 10 to 16% more dry matter than pure stand of vetch. The highest mean UFL yield (6,08x10^3units ha^{-1}) was also obtained from 50:50 mixture and the lowest (4.78x10^3 units ha^{-1}) from the pure stand of oat (Table 1). The highest mean CP yield (1.64 t ha^{-1}) was obtained from 50:50 mixture followed by pure stand of vetch (1.56 t ha^{-1}) (Table 2). Mixtures produced 600 to 780 kg ha^{-1} more CP yield than pure stand of oat. The mean PDI yield ranged from 485.7 kg ha^{-1} for pure stand of oat to 597.1 kg ha^{-1} for 50:50 mixture (Table 2).

Nutritional value of oat-vetch mixtures

Average UFL, CP, CF, TA, PDIN and PDIE contents of forages are presented in figure 2. Mean UFL concentration varied from 0.78 to 0.80 units per kilo of dry matter. Mean CF content ranged from 23.18% for 50:75 mixture to 26.40% for 50:50 mixture. Mean TA concentration varied from 11.29% for 50:50 mixture to 11.80% for 50:75 mixture. Mean CP concentration is affected by treatment ranging from 15.20% for pure stand of oat to 27.01% for pure stand vetch ($p<0.05$). Mean CP content increased 6.3% in 50:50 mixture and 4.6% in 50:75 mixture compared with pure stand of oat. Mean PDIN content varied significantly between treatments ($p<0.05$). The lowest value (103.5 g/kg DM) and the highest value (178.8 g/kg DM) of mean PDIN were obtained from pure stand of oat and pure stand of vetch respectively. Mean PDIE content was not affected by treatment ($p>0.05$). The highest value (80.2 g/kg DM) was obtained from the pure stand of oat while the lowest value (71.2 g/kg DM) was obtained from 50:75 mixture.

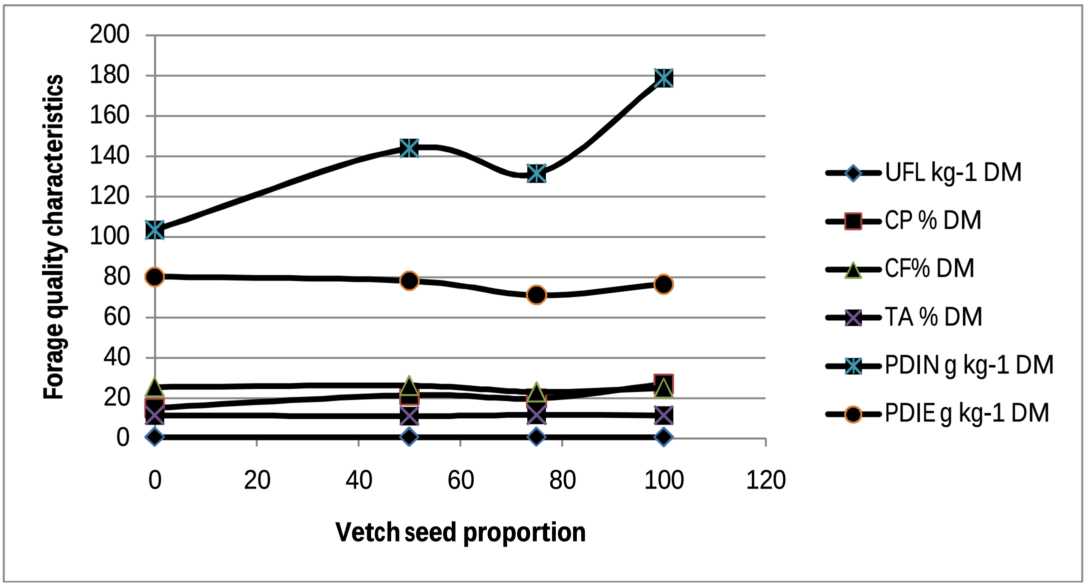

Figure 2: Mean Nutritive value of pure stands and mixtures of oat and vetch

DM: dry matter, UFL: Feed Unit for Lactation, CP: crude protein, CF: crude fibre, TA: total ash, PDIN: protein digested in the small intestine when rumen-fermentable nitrogen is limiting, PDIE: protein digested in the small intestine when rumen-fermentable energy is limiting.

Biological competition functions of oat-vetch mixtures

In the data averaged over the two sites, land equivalent ratio (LER) values for dry matter of both mixtures exceeded unity (Table 3). The combined LER values were 1.26 and 1.20 for 50:50 and 50:75 mixture, respectively. Vetch rate in dry matter production varied from 23.5 to 32%. The product of crowding coefficient (K) values were greater than one with K=22.45 for 50:50 mixture and K=2.97 for 50:75 mixture. For both mixtures, higher competitive ratio (CR) values and positive agressivity (A) values of oat were recorded (Table 3). The highest CR and A values (AI = ± 0.707 CR = 3.55) were obtained from 50:50 mixture.

DISCUSSION

At the first site (Antsirabe), DM, UFL, CP and PDI yields were significantly different among pure stands and mixtures ($p<0.001$) (Table 1). The highest value (7.64 t ha^{-1}) and the lowest value (5.41 t ha^{-1}) in DM yield were obtained from 50:50 mixture and pure stand of vetch, respectively. The superior dry matter production in pure stand of oat and mixtures compared to pure stand of vetch reflects the ability of grass to produce high levels of production. Similar results have been reported by other researchers [16, 17]. The highest CP yield (1.52 t ha^{-1}), UFL yield (6.31x10^{3} UFL ha^{-1}) were also recorded for the 50:50 mixture (Tables 1 and 2). Pure stand of vetch had higher CP yield than 50:75 mixture and pure stand of oat due to higher CP content (unpublished data). At the second site (Betafo), differences in DM, UFL, CP and PDI yields were also significant between treatments ($p<0.001$) (Tables 1 and 2). Mixture with the highest vetch rate (50:75) gave the highest DM yield (8.62 t ha^{-1}) followed by pure stand of vetch (7.87 t ha^{-1}). This is probably related to better growth of the legume on soil of parent materiel from recent volcanic origin. Mixtures produced higher UFL, CP and PDI yields than pure stands of either species which indicates optimal combination of biomass production and forage quality.

According to the two site's results average, DM, UFL, CP and PDI yields were not affected by treatment ($p>0.05$). The highest yields in DM (7.71 t ha^{-1}), UFL (6.08x10^{3} UFL ha^{-1}) and PDI (597.1 kg ha^{-1}) were obtained from the 50:50 mixture followed by the 50:75 mixture. The highest yields in mean CP were recorded for 50:50 mixture and pure stand of vetch. Hence, higher CP concentration in pure stand of vetch had compensated for lower dry matter production. In fact, forage quality characteristics were similar between treatments expect for mean CP and PDIN contents. Significantly higher CP and PDIN concentrations were recorded for pure stand of vetch compared to pure stand of oat ($p<0.05$). Mixtures had 4.6 to 6.3% more CP content and 15.6 to 39.1% more PDIN content than pure stand of oat. The same findings have been reported in other studies [18, 19]. Higher forage quality characteristics in mixtures compared to pure stand of oat are probably associated with the increased forage production.

With respect to biological competition functions, land equivalent ratio (LER) reflects the extra advantage of intercropping system over sole cropping system. In both mixtures, LER value for vetch was lower than 0.5, which indicated advantage of vetch for oat in intercropping. Combined LER values exceeded unity which showed an advantage of intercropping over sole system in terms of the use of environmental resources for plant growth. The results indicate that 20 to 26 % area would be required by a sole cropping system to recover the yield of intercropping system. *Karadag et al* reported that mean LER value for dry matter was 1.78 in vetch and grasspea-barley mixtures [20]. In both mixtures, the value of relative crowding coefficient (K) for oat exceeded unity and was higher compared to vetch. It indicated that oat was more competitive than vetch. As K value is higher in 50:50 mixture compared to the 50:75 mixture, oat competitive effect was higher. The value of the product of crowding coefficients was more than 1.00 in both mixtures, which further represented intercropping advantage over sole cropping. The 50:50 mixture achieved the highest K value (22.45). Similar results have been reported by *Banik et al* in chickpea-wheat intercropping [21]. The results of agressivity (A) showed that oat was the dominant species with positive values in the intercropping systems over vetch which had negative A values. However, 50:75 mixture had the value of almost zero aggressivity coefficients (± 0.012) which indicated mutual compatibility of the two component species under this combination. The dominant behaviour of cereal having positive A values when grown in association with legume was also reported in previous cereal-legume mixture studies [22, 23]. The similar trend of dominant behaviour of oat to vetch by K and A was also observed for CR. Values for competitive ratios for oat were higher than those of vetch in both mixtures. It revealed that oat was more competitive than vetch.

CONCLUSION

This study highlighted the benefits of intercropping oat with vetch for maximizing forage yield and quality. Intercropping of oat with vetch has not only enhanced dry matter production but also raised the quality of the forage produced, in particular the CP and PDIN concentrations. As oat-vetch seed proportions of 50:50 (50:30 kg ha^{-1}) provided better exploitation of the environment resources and achieved maximum yields advantage with respect to biomass, energy and protein yields, it is therefore recommended for the central highlands of Madagascar to improve forage production and quality, especially during the dry season hence to increase farmers' incomes and to contribute to poverty reduction.

AJFAND ONLINE
Volume 10 No. 10
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Table 1: Dry matter and feed unit for lactation of pure stands and mixtures of oat and vetch

Seed proportions	**Dry matter yield (t/ha)**				**Feed unit for lactation yield (x10^3/ha)**			
	Antsirabe	Betafo	Mean	±SD	Antsirabe	Betafo	Mean	±SD
100% oat	6.44	5.52	5.98	± 0.906	5.18	4.39	4.78	± 0.742
100% vetch	5.41	7.87	6.64	± 2.314	4.23	5.75	4.99	± 1.588
50% oat-50% vetch	7.64	7.79	**7.71**	± 0.876	6.31	5.86	**6.08**	± 0.694
50% oat-75% vetch	6.21	8.62	7.42	± 1.487	5.16	6.70	5.93	± 0.978
Mean	6.42	7.45	6.94	± 1.524	5.22	5.67	5.45	± 1.116
SE	0.35	0.65	0.73	± 0.380	0.31	0.47	0.56	± 0.279
F-test of probability	P<0.001	P<0.001	ns		P<0.001	P<0.001	ns	

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AJFAND ONLINE
Volume 10 No. 10
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Table 2: Crude protein and Protein digested in the small intestine yield of pure stands and mixtures of oat and vetch

Seed proportions	Crude protein yield (t/ha)				Protein digested in the small intestine yield (kg/ha)			
	Antsirabe	Betafo	Mean	±SD	Antsirabe	Betafo	Mean	±SD
100% oat	0.91	0.81	0.86	± 0.117	503.4	468	485.70	± 142.95
100% vetch	1.43	1.69	1.56	± 0.437	417.46	593.56	505.51	± 180.68
50% oat-50% vetch	1.52	1.76	**1.64**	± 0.238	585.15	609.09	**597.12**	± 54.43
50% oat-75% vetch	0.89	2.02	1.46	± 0.656	455.2	597.93	526.56	± 96.98
Mean	1.18	1.57	1.38	± 0.489	490.3	567.14	528.72	± 122.37
SE	0.12	0.19	0.23	± 0.122	35.61	48.18	59.91	± 30.59
F-test of probability	P<0.001	P<0.001	ns		P<0.001	P<0.001	ns	

Table 3: Mean biological potentials of pure stands and mixtures of oat and vetch

Seed proportions	Mean dry matter yield (t/ha)	LERO	LERV	LER	AO	AV	KO	KV	K	CRO	CRV
100% oat	5.97										
100% vetch	6.64										
50% oat + 50% vetch	7.69 (5.88+1.81)	0.983	0.276	1.26	0.71	-0.71	58.8	0.38	22.5	3.55	0.28
50% oat + 75% vetch	7.39 (5.02+2.37)	0.842	0.358	1.20	0.01	-0.01	7.99	0.37	2.97	3.52	0.28

LERO = land equivalent ratio for oat, LERV = land equivalent ratio for vetch, LER = combined land equivalent ratio, A = agressivity, K = Product of crowding coefficient, CR = competitive ratio

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