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Effects of Intercropping and Rotation on Forage Yield and Quality of Oat and Common Vetch in Jilin Province, China

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ABSTRACT

The effects of intercropping row ratio and rotation on forage yield and quality of oat and common vetch were studied to understand the possibility intercrop advantages. Oat and common vetch were intercropped twice a year for three years in the field of Baicheng Academy of Agricultural Science in Jilin Province, China. The oat to common vetch intercropping rates expressed as the ratio of the numbers of rows were 0:1, 1:3, 1:2, 1:1, 2:1, 3:1 and 1:0. The intercropping advantage became significant over the years. In 2009 and 2010, intercrop sown at the row rate of 1:1, showed 97% and 23% of forage yield increase mono-cropped common vetch; and 42% and 54% increase compare to mono-cropped oat, respectively. Nitrogen yield of the intercrop was 24% and 20% lower than mono-cropped common vetch in 2009 and 2010, but it was 79% and 93% higher than mono-cropped oat, respectively. Compared with mono-crop, intercropping presented positive effects on oat growth and dry matter accumulation, but negative effects on common vetch growth. Intercropping advantages exist when this positive effects surpluses the negative effects. Compared with continuous cropping, rotation has positive effects on oat. The effects of rotation on common vetch depended on soil nitrogen content. Higher soil N led to positive effects, while rotation on low soil N may inhibit common vetch growth. Intercropping oat with common vetch at row ratio of 1:1 under relatively low soil N content and rotation can produce the highest forage and N yield.

***Keywords**:* Intercropping, Rotation, Oat, Common Vetch.

INTRODUCTION

It is estimated that annual N_2 fixation inputs from pasture and fodder legumes to soil are 12-25 Tg (Herridge *et al.*, 2008; Yong *et al.*, 2017). The two ways to make full use of this property is to intercrop or rotate legumes with cereals, which had been practiced long before being scientifically studied. In the late 20^{th} century, as modern agriculture became industrialized, the difficulties of managing the intercropped plants mechanically, and the facilities in using chemical nitrogen fertilizer had caused a mass reduction of these practices (Anil *et al.,* 1998). However, as the problem of nitrogen overuse and pollution arises in the new system (Bijay-Singh *et al.*, 1995; Broumand *et al.*, 2010; Moradi et al., 2010; Soleymani and Shahrajabian, 2011; Soleymani and Shahrajabian, 2012; Shahrajabian *et al.*, 2013; Soleymani *et al.*, 2013), the practice of using the N_2-fixing ability of legumes in intercropping and rotation to reduce the application of N fertilizer had drawn new attention (Stern, 1993). Intercropping is defined as the growth of two or more crop species simultaneously in the same field during a growing season (Soleymani *et al.*, 2011; Soleymani and Shahrajabian, 2012; Soleymani *et al.*, 2012), and crop rotation is the practice of growing different plant species sequentially on the same land (Karlen *et al.*, 1994). The several advantages of intercropping include increased water and nutrition use efficiency (Sharma and Gupta, 2002; Walker and Ogindo, 2003), increased total crop yield (Bedoussac and Justes 2010a), better pest control and reduced risks of crop failure (Mariotti *et al.*, 2009), or better weed control (Workayehu and Wortmann, 2011). Crop rotation has most of the above advantages and also effects on soil structure (Ball *et al.*, 2005). The competitiveness of the intercropped plants are different. Usually cereals grow faster at early stages and are dominant in the intercrop (Jensen, 1996b; Sobkowicz, 2006; Bedoussac and Justes, 2010b). Over yielding of the intercrop may occur when competition between species is lower than within the same species. Different seeding rates of the intercrop may affect the competitiveness and growth of the crops (Kwabiah, 2005; Dhima *et al.*, 2007; Shobeiri *et al.*, 2010). Oat (*Avena sativa* L.) is the 4th largest forage crop in China and is receiving increased attention in recent years as land degradation and shortage of forage resources become serious. Combining the production of oat with common vetch (*Vicia sativa* L.) through intercropping and rotation is feasible, because as forage crops, they can be sown and harvested together without considering their different seed maturing time. The stem of oat may provide a support for common vetch and prevent its lodging, thus facilitate technical harvest (Waterer *et al.*, 1994). In previous studies, the yield of oat-common vetch intercrop was less than oat mono-crop under different seeding ratios (Caballero *et al.*, 1995; Lithourgidis *et al.*, 2006).

The objectives of this study were: 1) to find out if there is yield advantage for intercropped oat and common vetch under different row ratios 2) to determine the effects of intercroping on growth of the species and 3) to assess the effect of rotation on crop production over the years.

MATERIALA AND METHODS

Soil and growing conditions

A 3-year experiment was carried out in Baicheng Academy of Agricultural Sciences of Jilin province, China (45º37'N，122º48'E), during the growing seasons (April-October) of 2008-2010. The experiment was established in a sandy loam soil (pH, 6.86, organic matter content in 0-20cm depth 1.24%, total N 0.859 g kg^{-1}), alkali-hydrolyzable N 66.6 mg kg^{-1}, P（Olsen）14.2 mg kg^{-1} and K 71.8 mg kg^{-1}). Weather data were recorded daily from nearby weather station and were reported as monthly mean values for the 3 years (Figure 1).

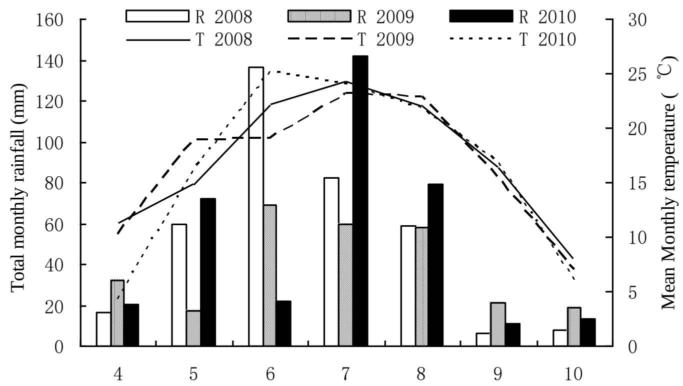

Figure 1. Monthly rainfall and mean air temperature during the 3 growing seasons of the experiment.

Experimental design

With oat being preceding crop, hulled oat (var. Baiyan.7) and common vetch (var. 333/A) were either mono-cropped or intercropped in 5 rates with a row-replacement design. Seeding rate of each rows were the same in monoculture and inter-crop planting. The intercropping ratio of oat to common vetch (expressed as ratio of the number of rows), sowing area proportion of oat, and seeding rate of the two crops in the 7 treatments are listed in Table 1.

Table 1. Oat common vetch row ratio, sowing area proportion, seeding rate

Treatments	T1	T2	T3	T4	T5	T6	T7
Oat : common vetch	0：1	1：3	1：2	1：1	2：1	3：1	1：0
Sowing area proportion of oat	0	0.25	0.33	0.50	0.67	0.75	1
Oat seeding rate (kg ha^{-1})	0	43.8	58.3	87.5	116.7	131.3	175
Common vetch seeding rate (kg ha^{-1})	150	112.5	100.1	75.0	50.0	37.5	0

To make the greatest use of light and heat resources, crops were cultivated for two seasons a year, namely previous and following crop, each lasted from April to July and from July to October. The 7 treatments of the previous crop were arranged in randomized complete block design with 3 replications. In each 4m×12m plot, 12 rows of oat or common vetch were planted with 33cm row spacing. In July after the harvest of the previous crop, each plot were divided into two 4m×5.5m sub-plots and the following crop was sown. One sub-plot was continuously cropped with the same arrangement of the previous crop; while the other sub-plot had a rotation treatment by planting oat to where the common vetch was planted in the previous crop and planting common vetch where oat was the previous crop. So the row ratio was also changed in the rotated sub-plot (e.g. 1:3 to 3:1, and 1:0 to 0:1, etc.).

At sowing 25.9kg of P_2O_5 ha^{-1} and 17.2kg of K_2O ha^{-1} were applied to the field. No N fertilizer was used. Irrigation was sufficient and unified cross all treatments with approximately 200mm per year.

Sampling and data

No samples were collected during growth period of 2008. In 2009, the previous crop was sampled 3 times at jointing, heading and milk stages; and the following crop was sampled 2 times at jointing and heading stages. In 2010, the previous crop was sampled at booting and milk stages, and the following crop was sampled at jointing and booting stages. A row of 50 cm long of oat or common vetch was carefully dug out from the field with a shovel. Plants' roots were washed and the number of plants and stems were counted. Ten plants were randomly selected to measure plant height. Plants' shoot was oven-dried at 75℃ to constant weight and weighed. The dried plants were then milled to fine powder and the total N content was analyzed with Kjeldahl method.

In the previous crop, oat was harvested at milk stage, while at the meantime common vetch was at podding stage. In the following crop, oat was harvested at heading stage, while the common vetch was at flowering stage. Two $1m^2$ areas in each plot were chosen to determine the fresh weight of the forage. Above ground fresh samples were collected and weighed separately for oat and common vetch. Some fresh samples were further oven-dried to measure water content.

The growth situation of oat and common vetch was expressed as dry matter accumulation of each 50cm row, and the yield of mixed forage was expressed as the total dry weight per $1m^2$, within which the seeding ratio of oat and common vetch was the same to each treatment. Analysis of variance was carried out on SAS software using the ANOVA procedure, Duncan's multiple range test $p< 0.05$ was used for mean comparisons.

RESULTS

Forage yield of the previous crop

In 2008, the total forage yield increased with the sowing proportion of oat, and the highest yield (11.8t ha^{-1}) was achieved by mono-cropped oat; common vetch accounts for little in the yield mixture. In 2009 and 2010 the highest yields (11.08 and 10.8t ha^{-1}, respectively) were achieved by treatment 4 (T4, Oat: Common vetch row ratio 1:1), which was significantly higher than the yields of the two mono-crops (Figure1).

From 2008 to 2010, the yield of mono-cropped oat showed a decreasing trend while the yield of mono-cropped common vetch increased. In the intercropped treatments, the proportion of the yield of common vetch in the total yield also increased through the years. Because no nitrogen fertilizer was applied during the experiment, this result may be explained as the effects of continuous cropping of cereals and legumes. As soil N was being consumed, the advantage of intercropping legumes with cereals became more prominent. The highest yields of 2008, 2009 and 2010 were 11.8, 11.08 and 10.8t ha^{-1}, respectively, showing the stability of this intercropping system.

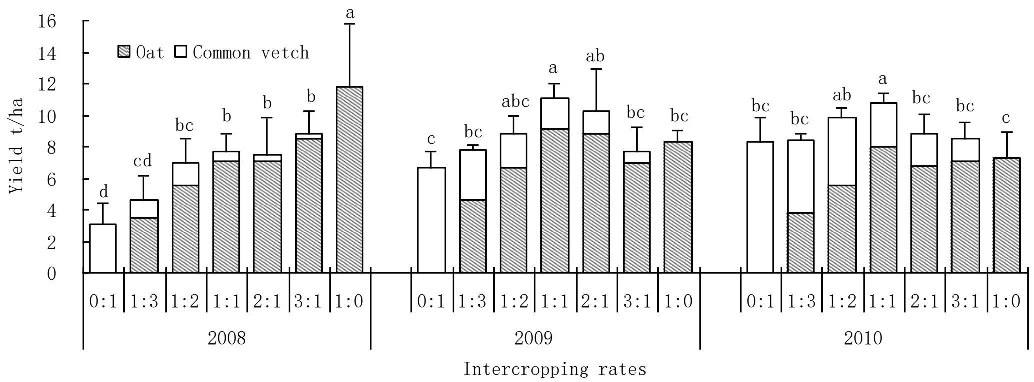

Figure 1. Effects of different intercropping rates on yield of oat and common vetch of previous crop (t ha^{-1})

Forage yield of the following crop

Because the intercropping row ratio changed with rotate practice, it is important to note that the following comparisons of yield between rotated and continuous cropped plots are based on the same intercropping row ratio (eg. If a rotated plot's row ratio was 1:3, then the continuous cropped plot that was comparable to it was also 1:3, not 3:1 which was its original ratio before rotation).

For mono-cropped common vetch, rotation with oat decreased the yield significantly in 2008 and 2010. For mono-cropped oat, rotate with common vetch increased the yield in 2009 and 2010 (Figure 2). For the intercrop treatments, rotated T4(1:1), T5(2:1) and T6(3:1) yielded constantly higher than continuously cropped plots during 3 years. The sowing area proportion of common vetch in the previous crop of T4, T5 and T6 were higher than 50%, indicating a positive effect of common vetch as a previous crop to oats.

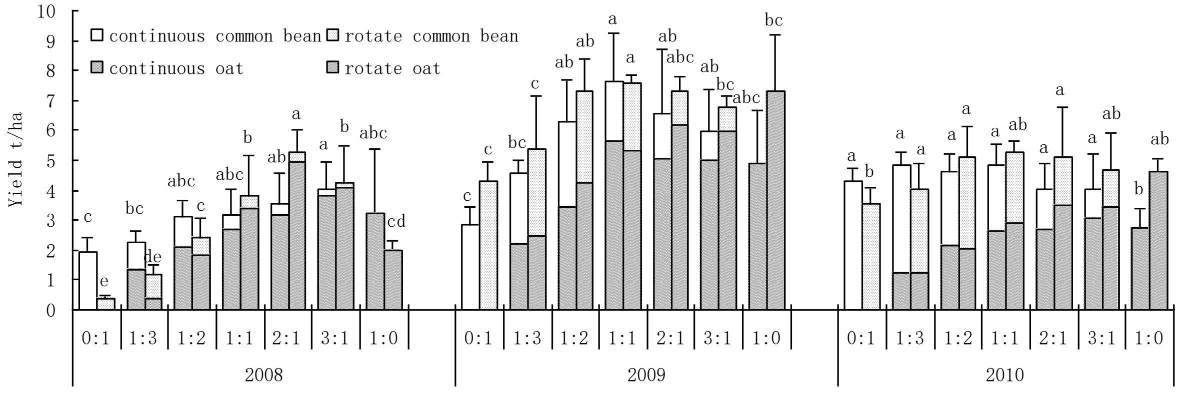

Figure 2. Effects of rotation on forage yield of the same intercropping rate (t ha^{-1})
Columns of the same rotate treatment with the same letters are not significantly different at $P<0.05$.

Land equivalent ratio (LER) of the previous crop

From 2008 to 2010, LER of the previous crop increased with year (Table 2). In 2008 T3 hadthe highest LER (, 0.93) which was less than 1 and, indicating negative effects of intercroping on yield. In 2009 the highest LER (1.28) was achieved by T5, and in 2010 the highest LER (1.48) was found for T4, indicating the existence of intercropping advantage.

Table 2. Effects of different intercropping row ratio on LER

Treatment*	O:V	2008	2009	2010
T2	1:3	0.66	1.03	1.07
T3	1:2	0.93	1.13	1.27
T4	1:1	0.78	1.24	1.42
T5	2:1	0.75	1.28	1.18
T6	3:1	0.82	0.95	1.14

*Treatments are described in Table 1

Nitrogen content and nitrogen yield of the previous crop

Nitrogen content of common vetch was almost 2 times of oat, and intercropping did not significantly affected N content of either crops (Figure 3). Total N yield of the forage was mainly influenced by dry matter yield of the mixed forage. Because of its high N content, mono-cropped common vetch had the highest N yield and mono-cropped oat had the lowest, except for 2008 when forage yield of common vetch was very low.

N yield of mono-cropped oat remained constant from 2008 to 2010, while N yield of mono-cropped vetch increased from 75.5 kg ha^{-1} to 258.1 kg ha^{-1}. Intercropping with common vetch increased the N yield of the mixed forage. In 2010, N yield of T4 was 19.6% less than T1, and 92.7% more than T7; the proportion of common vetch in N yield of T4 is 38%. Unlike the case with forage yield that common vetch contributed to a proportion much less than its seeding row ratio, in the case of N yield common vetch contributed to a proportoin siminar to its seeding ratio in each treatment.

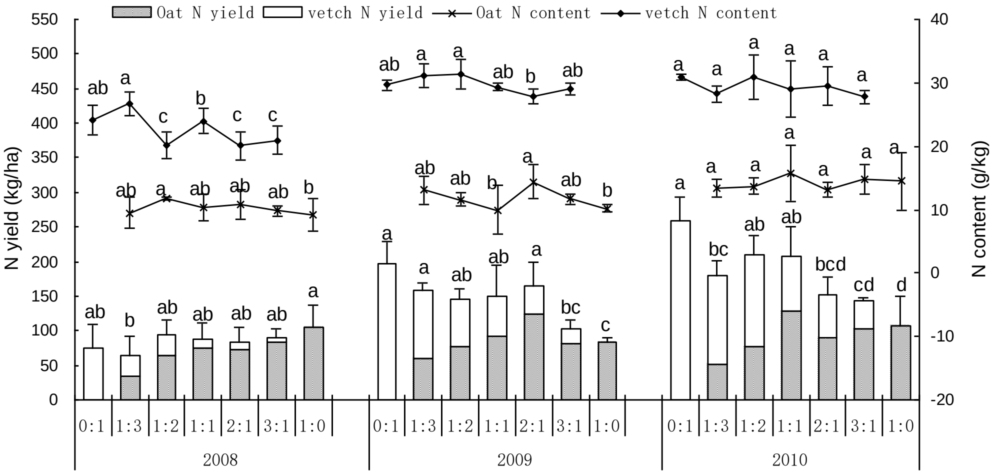

Figure 3. Effects of Intercropping rates on N content (g/kg) and N yield (kg ha^{-1}) of previous crop
Columns of the same treatment with the same letters are not significantly different at P<0.05.

Dry matter accumulation

Before the harvest time of the previous crop, dry matter accumulated by intercropped oat was significantly higher than mono-cropped oat (Figure 4). For 2009 and 2010, dry matter accumulation of oat increased as the proportion of common vetch in the intercrop increased, reached the peak at T3 (1:2), which had no significant differences with T2 (1:3) and T4 (1:1). In 2008 dry matter accumulation of oat in T4 was 20.5% higher than T7, and in 2009 and 2010 T4 was 2.2 times of T7 (p<0.05).

Accumulated dry matter in the following crop was less than previous crop, however the differences between treatments were smaller, which may be due to the lower temperature and slower growth rate of the following crop. For the same intercropping rate, rotated oat accumulated more dry matter than continuously cropped oat, but the difference was not significant.

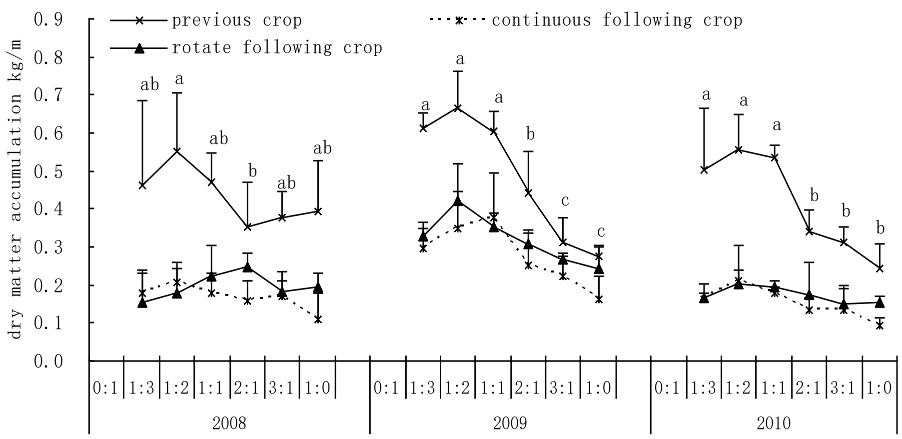

Figure 4. Effects of Intercropping and rotation on dry matter accumulation of oat (kg/m)
The same treatment with the same letters are not significantly different at P<0.05.

Unlike oat, the dry matter accumulation by common vetch in the previous crop was comparable with the following crop, showing that common vetch was more adapted to the light and temperature from July to October. Effects of intercropping and rotation on growth of common vetch was different in the 3 years (Figure 5). In 2008, the growth of common vetch was not adequate in all treatments, while intercropped as well as rotated common vetch showed a decrease in dry matter accumulation. For the previous crop in 2009 and 2010, dry matter accumulation by intercropped common vetch was less than mono-cropped T1. For the following crop in 2009, the effects of rotation differed at treatment T4. From T1 to T3, rotation increased dry matter accumulation; for T5 and T6 the continuously cropped vetch grew better. For the following crop in 2010, the rotated vetch grew better except for T1 and T2.

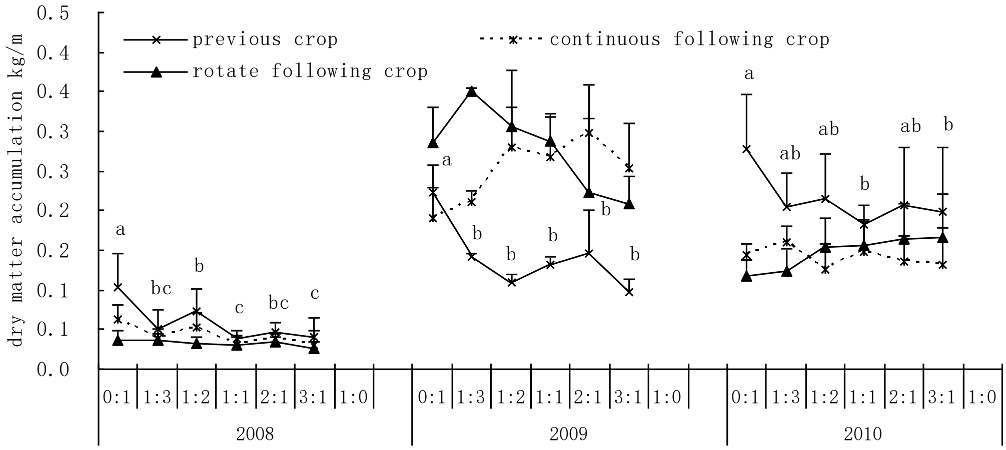

Figure 5. Effects of Intercropping and rotation on dry matter accumulation of Common vetch (kg/m)
The same treatment with the same letters are not significantly different at P<0.05.

Plant height

Plant height of the previous crop of mono-cropped oat was the lowest among the treatments and also continuous cropping of the following crop in 2009 and 2010. Except for T2 and T3 in 2009, all rotated treatments in the two years had higher plant height than continuous cropped treatments with the same intercropping row ratio. Both intercropping and rotation had positive effects on plant height of oat. Plant height of common vetch had greater coefficient of variation and thus differences were not so evident. Generally intercropping and rotation both had positive effects on plant height of common vetch (Table 3).

Branches and nodules of common vetch

Generally, intercropped common vetch had less branches than mono-cropped ones. N significant differences for number of branches was found between rotated and continuously cropping. Changes of root nodules were not evident because of the great coefficient of variation in the analysis (Table 4).

Table 3. Effects of Intercropping ratio and rotation on plant height of oat and common vetch (cm)

Treatments*	Oat			Common vetch		
	Previous crop	Continuous following crop	Rotated following Crop	Previous crop	Continuous following crop	Rotated following crop
2009						
0:1	—	—	—	107.0±11.9a	65.7±14.4b	73.4±7.9d
1:3	111.0±9.4c	92.0±8.8ab	83.5±6.1c	106.0±11.1a	89.4±12.0a	80.2±19.5cd
1:2	116.3±7.4b	94.5±4.4a	90.2±8.9b	91.5±21.2b	91.6±23.1a	89.9±12.9ab
1:1	118.3±10.7b	95.5±10.4a	96.8±5.5a	106.0±14.2a	65.7±14.4b	87.1±16.6bc
2:1	105.9±11.2c	84.9±12.3c	93.2±7.0b	71.6±24.6c	89.4±12.0a	89.2±16.0ab
3:1	126.1±10.8a	88.1±5.9bc	90.5±6.6b	102.2±13.3a	91.6±23.1a	96.2±10.2a
1:0	107.7±8.9c	73.7±6.3d	98.3±7.1a	—	—	—
2010						
0:1	—	—	—	44.8±5.6c	31.6±3.9c	36.4±4.6b
1:3	95.9±5.5bc	44.3±4.6b	46.7±6.1b	49.2±10.2ab	35.9±3.2b	37.1±4.6b
1:2	105.6±6.8a	41.9±2.9c	48.8±4.2ab	49.6±7.7ab	38.3±2.2a	35.8±4.4bc
1:1	98.6±5.7b	48.7±4.6a	49.5±4.2ab	52.8±8.3a	36.2±3.7b	40.3±4.4a
2:1	88.1±10.9d	45.0±7.1b	51.4±8.0a	42.9±9.9c	37.1±5.2ab	40.1±3.9a
3:1	92.3±7.9c	43.1±2.7bc	47.7±5.4b	46.5±4.4bc	35.9±3.6b	34.3±3.8c
1:0	79.4±9.4e	39.2±4.1d	48.1±7.7ab	—	—	—

*: Treatments are defined in Table 1.
Means in the same column followed by the same letters are not significantly different at P<0.05.

Table 4. Effects of intercropping and rotation on branches and nodules of Common vetch

Treatment*	Branches			Root nodules		
	Previous crop	Continuous following crop	Rotative following crop	Previous crop	Continuous following crop	Rotative following crop
2009						
0:1	2.0±1.2 a	2.4±1.0 a	3.3±1.6 a	12.8±8.5 a	4.4±9.5 a	1.8±2.5 b
1:3	2.0±0.9 a	2.2±1.5 a	1.9±0.7 bc	12.4±15.0 a	2.9±5.1 a	0.8±2.1 b
1:2	1.7±0.9 a	0.9±0.8 b	2.1±1.0 b	8.9±7.2 ab	1.0±2.5 a	4.3±4.9 a
1:1	1.7±1.0 a	2.4±1.0 a	1.7±1.1 bc	8.3±9.3 ab	4.4±9.5 a	1.3±3.1 b
2:1	1.6±1.0 a	2.2±1.5 a	1.3±1.0 c	5.9±3.8 b	2.9±5.1 a	1.7±3.2 b
3:1	1.7±0.8 a	0.9±0.8 b	0.5±0.7 d	4.0±5.4 b	1.0±2.5 a	2.1±3.1 b
2010						
0:1	1.9±0.6 ab	3.0±1.0 a	2.9±1.0 ab	12.0±1.6 cd	13.4±2.4 a	14.5±2.6 a
1:3	1.8±0.9 b	2.4±0.9 ab	2.8±0.9 abc	12.8±1.8 ab	14.2±2.4 a	14.0±2.4 a
1:2	2.0±0.8 ab	2.3±0.9 b	2.5±0.8 bc	13.3±1.3 a	13.6±2.6 a	13.7±2.2 a
1:1	1.9±0.6 ab	2.4±0.9 ab	2.3±1.0 c	13.1±1.3 ab	13.1±2.3 a	14.6±2.1 a
2:1	1.8±0.8 b	2.2±1.2 b	2.3±0.8 c	11.3±1.3 d	13.5±1.9 a	14.0±2.2 a
3:1	2.3±0.7 a	2.5±1.2 ab	3.2±1.6 a	12.4±1.4 bc	13.1±2.5 a	14.7±2.0 a

*: Treatments are defined in Table 1.
Means in the same column followed by the same letters are not significantly different at P<0.05.

Soil N content after harvest

Analysis of the soil N content after harvest of the following crop in 2010 showed that the effects of the treatments became evident after 6 times of harvest in 3 years. T4(1:1) and T5(1:2) treatments had the highest soil N content while T7 had the lowest, and the differences were significant ($P<0.05$). Soil N content of the rotated treatments were slightly higher than continuous cropped ones, and the difference was significant for T7 ($P<0.05$). This gives direct evidence for the positive effects of intercropping and rotation of oat and common vetch on soil fertility (Figure 6).

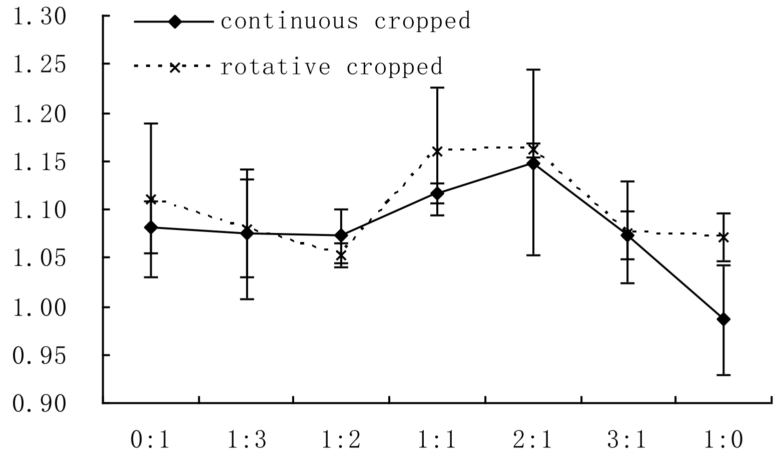

Figure 6. Effects of Intercropping and rotation on soil total N content (g/kg) after 2010 harvest.

DISCUSSION

Forage yield and quality

Except for 2008, for the previous crop of 2009 and 2010 the mixed forage yielded higher than mono-cropped oat. Among the intercropping rates T4 yielded the highest, so that in 2009 and 2010 it was 33% and 47% higher than T7, and 66% and 29% higher than T1, respectively. For nitrogen yield of the mixed forage, except for 2008, the intercropped treatments yielded higher than mono-cropped oat. In 2010, the nitrogen yield of T4 was 19.6% lower than T1, and 92.7% higher than T7. Because 2008 was the first year of the study and the soil fertility was relatively high, the well-established oat greatly influenced common vetch growth. In 2009 and 2010, as soil N decreased, the intercropping advantage became evident, and the forage and nitrogen yield of mixed forage became higher than mono-cropped oat. The dry matter accumulation and plant height of intercropped oat was higher than mono-cropped oat, indicating positive effects of intercropping. On the contrary, the dry matter accumulation and numbers of branches were decreased for intercropped common vetch, indicating the overall effects of intercropping on common vetch was negative although plant height was increased. The yield of the mixed forage was affected by the combined effects of intercropping on oat (positive) and common vetch (negative). In T4 treatments for example, dry matter accumulations of mono-cropped oat in 2009 and 2010 were 0.28 and 0.24kg/m, and for common vetch were 0.22 and 0.28kg/m and was very close to oat. When intercropped, dry matter accumulation of oat was increased by 220% in both days and that of common vetch was decreased by 40% and 34%. The yield data of mono-cropped crops were similar, thus when intercropped, with much higher increase of oat yield than the decrease yield of common vetch, the overall yield of the mixture was higher than either mono-cropped crops.

The positive effects of intercropping on oat may be due to the results of improved light interception, reduced water competition, and transferred nitrogen from common vetch to oat or released competition of nitrogen. Light plays an important role in intercrop advantage (Szumigalski and Van Acker, 2008; Zhang *et al*., 2008); when intercropped with durum wheat, the growth rate of pea was slower than mono-cropped ones because of shading effects (Bedoussac and Justes, 2010b), and when maize was intercropped with cowpea, photosynthetically active radiation (PAR) of maize was increased and cowpea was shaded and decreased in crude protein content (Eskandari *et al*., 2009; Ghanbari *et al*., 2010), and peanut intercropped with maize decreased in yield because of less received light (Awal *et al*., 2006). A study on intercropping of barley and pea showed that barley had stronger competitiveness than pea (Jensen, 1996a), which may be the results of the deeper and faster root development of barley (Hauggaard-Nielsen *et al*., 2001). For legumes, intercropping with cereals may enhance its nitrogen-fixing rate (Danso *et al*., 1987; Sangakkara, 1994; Hauggaard-Nielsen *et al*., 2009), thus alleviate the competition of soil nitrogen.

Forage yield and quality

There were three intercropping treatments that yielded higher for the rotated plots in the 3 years:T4, T5 and T6, in which oat held for more than 50% of the sowing area proportion. On the contrary, in their previous crop common vetch accounted for more than 50% in the row ratio. This clearly showed the positive effect of common vetch as the previous crop on oat as the following crop. This may be the results of increased input of nitrogen into the soil by crop residue (Patra *et al*., 1987),or improved soil nitrogen balance (Adu-Gyamfi *et al*., 2007).

The dry matter accumulation and plant height of rotated common vetch differed in the three years. The effect of oat as a previous crop to following common vetch may be different. The decreased of soil nitrogen may alleviate the inhibitory effect of nitrogen on symbiotic N2 fixation (Li *et al*., 2009), thus enhance the growth of common vetch, which may be the case of 2009. If the soil nitrogen continue to decrease to an extent that early establishment of common vetch is affected, then the growth and nitrogen fixation may also be reduced (Van Kessel and Hartley, 2000), which may be the case of 2010.

Interspecific competition and intercropping advantage

The highest yield of the previous crop in 2008, 2009 and 2010 were 11.8 t ha^{-1}, 11.1t ha^{-1}, and 10.8 t ha^{-1}, respectively. Comparing with the yield decrease of mono-cropped oat in the three years, intercropping system had relatively steady yield performance under the condition of low nitrogen input over years.

Oat and other cereals had higher interspecific competitiveness with sufficient soil nitrogen supply (Bedoussac and Justes, 2010b). This may explain the low yield of common vetch in 2008, and the result of lower yield of intercrop to mono-cropped cereals (Lithourgidis *et al*., 2007). When soil nitrogen was lower in 2009 and 2010, the competitiveness and yield of common vetch increased, and the yield of intercrop surpluses mono-cropped oat.

Better intercropping advantage can be achieved under low soil nitrogen condition, as verified by the increase of the highest land equivalent ratio of the intercrop in the three year from 0.93,1.28 to 1.42. LER of other studies are mostly around 1.3 (Bulson *et al*., 1997; Hauggaard and Nielsen *et al*., 2009; Li *et al*., 2009).

CONCLUSION

The intercropping advantage of oat and common vetch became significant over the years. Intercroping with sowing row ratio of 1:1. In 2009 and 2010, the forage yield of the intercrop was 97% and 23% higher than mono-cropped common vetch, and 42% and 54% higher than mono-cropped oat. In 2009 and 2010 the nitrogen yield of the intercrop was 24% and 20% lower than mono-cropped common vetch, but 79% and 93% higher than mono-cropped oat. Compared to mono-crop, intercropping had positive effects on growth and dry matter accumulation of oat, but negative effects on common vetch. Intercropping advantage exist when positive effects surpluses the negative effect. Compared with continuous cropping, rotation had positive effects on oat. The effects of rotation on common vetch depends on soil nitrogen content. Higher soil N may lead to positive effects, while rotation on low soil N may inhibit the growth of common vetch. Intercropping oat with common vetch at row ratio of 1:1 under relatively low soil N content and rotation can produce the highest forage and N yield.

REFERENCES

Adu-Gyamfi JJ, Myaka FA, Sakala WD, Odgaard R, Vesterager JM, Høgh-Jensen H. 2007. Biological nitrogen fixation and nitrogen and phosphorus budgets in farmer-managed intercrops of maize-pigeonpea in semi-arid southern and eastern Africa. Plant Soil, 295: 127-136.

Anil L, Park J, Phipps RH, Miller FA. 1998. Temperate intercropping of cereals for forage: A review of the potential for growth and utilization with particular reference to the UK. Grass Forage Science, 53: 301-317.

Awal MA, Koshi H, Ikeda T. 2006. Radiation interception and use by maize/peanut intercrop canopy. Handbook of Environmental Chemistry, Volume 5: Water Pollution, 139: 74-83.

Ball BC, Bingham I, Rees RM, Watson CA, Litterick A. 2005. The role of crop rotations in determining soil structure and crop growth conditions. Canadian Journal of Soil Science, 85: 557-577.

Bedoussac L, Justes E. 2010a. The efficiency of a durum wheat-winter pea intercrop to improve yield and wheat grain protein concentration depends on N availability during early growth. Plant Soil, 330: 19-35.

Bedoussac L, Justes E. 2010b. Dynamic analysis of competition and complementarity for light and N use to understand the yield and the protein content of a durum wheat-winter pea intercrop. Plant Soil, 330: 37-54.

Bijay-Singh, Yadvinder-Singh, Sekhon GS. 1995. Fertilizer-N use efficiency and nitrate pollution of groundwater in developing countries. Journal of Contaminate Hydrology. 20: 167-184.

Broumand P, Rezaei A, Soleymani A, Shahrajabian MH, Noory A. 2010. Influence of forage clipping and top dressing of nitrogen fertilizer on grain yield of cereal crops in dual purpose cultivation system. Research on Crops, 11(3): 603-613.

Bulson HAJ, Snaydon RW, Stopes CE. 1997. Effects of plant density on intercropped wheat and field beans in an organic farming system. Journal of Agricultural Science, 128: 59-71.

Caballero R, Goicoechea EL, Hernaiz PJ. 1995. Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of vetch. Field Crop Research, 41: 135-140.

Danso SKA, Zapata F, Hardarson G, Fried M. 1987. Nitrogen fixation in fababeans as affected by plant population density in sole or intercropped systems with barley. Soil Biology and Biochemistry, 19: 411-415.

Dhima KV, Lithourgidis AS, Vasilakoglou IB, Dordas CA. 2007. Competition indices of common vetch and cereal intercrops in two seeding ratio. Field Crop Research, 100: 249-256.

Eskandari H, Ghanbari-Bonjar A, Galavi M, Salari M. 2009. Forage quality of cow pea (*Vigna sinensis*) Intercropped with corn (*Zea mays*) as affected by nutrient uptake and light interception. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 37: 171-174.

Ghanbari A, Dahmardeh M, Siahsar BA, Ramroudi M. 2010. Effect of maize (*Zea mays* L.*)* - Cowpea (*Vigna unguiculata* L.) intercropping on light distribution, soil temperature and soil moisture in arid environment. Journal of Food, Agriculture and Environment, 8: 102-108.

Hauggaard-Nielsen H, Ambus P, and Jensen ES. 2001. Interspecific competition, N use and interference with weeds in pea-barley intercropping. Field Crop Research, 70: 101-109.

Hauggaard-Nielsen H, Gooding M, Ambus P, Corre-Hellou G, Crozat Y, Dahlmann C, Dibet A, von Fragstein P, Pristeri A, Monti M, Jensen ES. 2009. Pea-barley intercropping for efficient symbiotic N2-fixation, soil N acquisition and use of other nutrients in European organic cropping systems. Field Crop Research, 113: 64-71.

Herridge DF, Peoples MB, Boddey RM. 2008. Global inputs of biological nitrogen fixation in agricultural systems. Plant Soil, 311: 1-18.

Jensen ES. 1996a. Grain yield, symbiotic N2 fixation and interspecific competition for inorganic N in pea-barley intercrops. Plant Soil, 182: 25-38.

Karlen DL, Varvel GE, Bullock DG, Cruse RM. 1994. Crop Rotations for the 21st Century. Advance in Agronomy, 53: 1-45.

Kwabiah AB. 2005. Biological efficiency and economic benefits of pea-barley and pea-oat intercrops. Journal of Sustainable Agriculture, 25: 117-128.

Li YY, Yu CB, Cheng X, Li CJ, Sun JH, Zhang FS, Lambers H, Li L. 2009. Intercropping alleviates the inhibitory effect of N fertilization on nodulation and symbiotic N2 fixation of faba bean. Plant Soil, 323: 295-308.

Lithourgidis AS, Dhima KV, Vasilakoglou IB, Dordas CA, Yiakoulaki MD. 2007. Sustainable production of barley and wheat by intercropping common vetch. Agronomy

for Sustainable Development, 27: 95-99.
Lithourgidis AS, Vasilakoglou IB, Dhima KV, Dordas CA, Yiakoulaki MD. 2006. Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. Field Crop Research, 99: 106-113.
Mariotti M, Masoni A, Ercoli L, Arduini I. 2009. Above- and below-ground competition between barley, wheat, lupin and vetch in a cereal and legume intercropping system. Grass Forage Science, 64: 401-412.
Mordai K, Shangari AH, Shahrajabian MH, Gharineh MH, Madandost M. 2010. Isabgol (*Plantago ovata Forsk*.) response to irrigation intervals and different nitrogen levels. Iranian Journal of Medicinal and Aromatic Plants, 26(2): 196-204.
Patra DD, Sachdev MS, Subbiah BV. 1987. Forms of fertilizer nitrogen residues in soil after intercropping of maize-cowpea. Biology and Fertility of Soils, 4: 155-161.
Sangakkara R. 1994. Growth, yield and nodule activity of mungbean intercropped with maize and cassava. Journal of the Science of Food and Agriculture, 66: 417-421.
Shahrajabian MH, Xue X, Soleymani A, Ogbaji PO, Hu Y. 2013. Evaluation of physiological indices of winter wheat under different irrigation treatments using weighing lysimeter. International Journal of Farming and Allied Sciences, 2(24): 1192-1197.
Sharma OP, Gupta AK. 2002. Nitrogen-phosphorus nutrition of pearlmillet as influenced by intercrop legumes and fertilizer levels. Journal of Plant Nutrition, 25: 833-842.
Shobeiri S, Habibi D, Kashani A, Paknejad F, Jafari H, Al-Ahmadi MJ, Tookalloo MR, Lamei J. 2010. Evaluation of hairy vetch (*Vicia villosa Roth*) in pure and mixed cropping with barley (*Hordeum vulgare L*.) to determine the best combination of legume and cereal for forage production. American Journal of Agricultural and Biological Science, 5: 169-176.
Soleymani A, Shahrajabian MH. 2011. Effect of planting dates and different levels of nitrogen on seed yield and yield components of safflower grown after harvesting of corn in Isfahan, Iran. Reseach on Crops, 12(3): 739-743.
Soleymani A, Shahrajabian MH, Naranjani L. 2011. Changes in qualitative characteristics and yield of three cultivars of berseem clover intercropped with forage corn in low input farming system. Journal of Food, Agriculture and Environment, 9(1): 345-347.
Soleymani A, Shahrajabian MH. 2012. Influence of nitrogen fertilizer on ash, organic carbon, phosphorus, potassium and fiber of forage corn intercropped by three cultivars of berseem clover as cover crops in semi-arid region of Iran. International Journal of Biology, 4(3): 38-43.
Soleymani A, Shahrajabian MH. 2012. Effects of different levels of nitrogen on yield and nitrate content of four spring onion genotypes. International Journal of Agriculture and Crop Science, 4(4): 179-182.
Soleymani A, Shahrajabian MH, Naranjani L. 2012. Evaluation the benefits of different berseem clover cultivars and forage corn intercropping in different levels of nitrogen fertilizer. Journal of Food, Agriculture and Environment, 10(1): 599-601.
Soleymani A, Shahrajabian MH, Naranjani L. 2013. Effect of planting dates and different levels of nitrogen on seed yield and yield components of nuts sunflower (*Helianthus annuus L*.). African Journal of Agricultural Research, 8(46): 5802-5805.
Stern WR. 1993. Nitrogen fixation and transfer in intercrop systems. Field Crop Res, 34: 335-356.
Szumigalski AR, Van Acker RC. 2008. Land equivalent ratios, light interception, and water use in annual intercrops in the presence or absence of in-crop herbicides. Agronomy Journal, 100: 1145-1154.

Van Kessel C, Hartley C. 2000. Agricultural management of grain legumes: Has it led to an increase in nitrogen fixation? Field Crop Research, 65: 165-181.

Walker S, Ogindo HO. 2003. The water budget of rainfed maize and bean intercrop. Physics and Chemistry of the Earth, 28: 919-926.

Waterer JG, Vessey JK, Stobbe EH, Soper RJ. 1994. Yield and symbiotic nitrogen fixation in a pea-mustard intercrop as influenced by N fertilizer addition. Soil Biology and Biochemistry, 26: 447-453.

Workayehu T, Wortmann CS. 2011. Maize-bean intercrop weed suppression and profitability in Southern Ethiopia. Agronomy Journal, 103: 1058-1063.

Yong Y, Hu Y, Shahrajabian MH, Ren C, Guo L, Wang C, Zeng Z. 2017. Organic matter, protein percentage, yield, competition and economics of oat-soybran and oat-ground nut intercropping systems in Northern China. Cercetari Agronomice in Moldova, 3(171): 25-35.

Zhang L, van der Werf W, Bastiaans L, Zhang S, Li B, Spiertz JHJ. 2008. Light interception and utilization in relay intercrops of wheat and cotton. Field Crop Research, 107: 29-42.