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ORGANIC MATTER, PROTEIN PERCENTAGE, YIELD, COMPETITION AND ECONOMICS OF OAT-SOYBEAN AND OAT-GROUNDNUT INTERCROPPING SYSTEMS IN NORTHERN CHINA

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ABSTRACT. Intercropping is one of the most important and sustaibale cropping practice in agro-ecosystems. The study was conducted under field conditions in the arid Horqine sandy land in Baicheng District, Jilin Province, Northern China in 2011. A randomized complete block design with four replications was used. Treatments comprised different mono cropping and intercropping patterns, TO: sole cropping of oat, TOS-O: oat in the intercropping of oat and soybean, TOG-O: oat in the intercropping of oat and groundnut, TS: sole cropping of soybean, TOS-S: soybean in intercropping of oat and soybean, TG: sole cropping of groundnut, TOG-G: groundnut in the intercropping of oat and groundnut. In intercropping patterns, oat in oat-groundnut had obtained the highest dry matter in all stages. The highest value of protein percentage and organic matter in heading stage, grain filling stage, and grain dough stage was achieved in groundnut in oat-groundnut intercropping. The maximum value of protein percentage and organic matter in booting stage and ripening stage was related to soybean in oat-soybean intercropping. The results of this study clearly indicate that intercropping oat and groundnut affects the growth rate of the individual species in mixtures as well as the dry matter yield and nitrogen accumulation. The highest seed yield was obtained for mono-cropping of soybean, followed by mono-cropping of groundnut and oat. Oat seed yield intercropping of oat and groundnut, and intercropping of oat and soybean were 1208.00 kg/ha, and 832.3 kg/ha, respectively. The highest grain yield was obtained when soybean was grown together with oat, where the higher yield of intercrop is due to the better usage of nutrient, water

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and light. LER in all intercropping patterns were higher than 1. LER in intercropping of soybean and oat, and intercropping of groundnut and oat were 1.41, and 1.30, respectively. With these LER values, 29.07% and 23.07% of land were, respectively, saved in intercropping of soybean and oat, and intercropping of groundnut and oat, respectively, which could be used for other agricultural purposes. In both intercropping of soybean and oat, and intercropping of groundnut and oat, CI were less than 1, which means that both these two intercropping patterns have positive effects.

Keywords: organic matter; soybean; groundnut; oat; intercropping.

INTRODUCTION

Cereal-legume intercropping offers potential benefits in cropping systems, where nutrients, in particular nitrogen are limited (Banik *et al.,* 2006; Hauggaard-Nielsen *et al.,* 2009; Soleymani *et al.,* 2011; Soleymani & Shahrajabian, 2011; Soleymani *et al.,* 2012). The benefits of oat intercropping with other crops also reported by many researchers (Malézieux *et al.,* 2009; Naumann *et al.,* 2010; Begna *et al.,* 2011; Chen *et al.,* 2011; Han *et al.,* 2012). Researchers also reported the improvement of peanut production in intercropping system (Kadžiulienė *et al.,* 2011; Justino & Sodek, 2013). The inclusion of legumes in crop rotations and intercrops can provide increased protein-rich yields and a more sustainable source of nitrogen, while on the other side, it saves cost by reducing the requirement for mineral nitrogen application (Crew and Peoples, 2004). The land equivalent ration (LER) is defined as the relative land area growing sole crop that is required to produce the yields achieved when growing intercrops (Hauggaard-Nielsen *et al.,* 2006). Javanmard *et al.* (2009) also reported that LER is an index used for evaluating the effectiveness of all forms of intercropping. According to Jaurena *et al.* (2005), organic matter contents of barley grain, ryegrass silage and red clover silage were 919, 814 and 807 g/kg dry matter. Ebwongu *et al.* (2001) found that in potato and corn intercropping, LER reached to 1.58, showing the beneficial effect of intercropping. Dua *et al.* (2005) noted that intercropping treatments increased yield, as compared to sole cropping and the amount of LER was more than one. Bekele and Sommartya (2006) found that in intercropping of potato with garlic, the amount of LER reached more than one. Ijoyah & Fanen (2012) reported that 46.5% and 46.2% of land were, respectively, in 2009, and 2010 for maize-soybean mixture, which could be used for other agricultural purposes. Evaluation the benefits of oat-soybean and oat-groundnut intercropping, protein pecentage, yield and organic matter was studied in this research.

MATERIALS AND METHODS

The study was conducted under field conditions in the arid Horqine sandy land in Baicheng District (44°14′-46°18′N, 121°38′-124°22′E), Jilin Province, Northern China in 2011. A randomized

complete block design with four replications was used. Treatments comprised different mono cropping and intercropping patterns, TO: sole cropping of oat, TOS-O: oat in the intercropping of oat and soybean, TOG-O: oat in the intercropping of oat and groundnut, TS: sole cropping of soybean, TOS-S: soybean in intercropping of oat and soybean, TG: sole cropping of groundnut, TOG-G: groundnut in the intercropping of oat and groundnut. No nitrogen fertilizer was used in this research. 55 kg/ha P_2O_5, 45 kg/ha K_2O, 4.5 kg/ha $FeSO_4$, 1 kg/ha H_3BO_3, 1.5 kg/ha $Na_2MOO_4.2H_2O$ were applied as basal fertilizers. An automatic weather station was installed in the experimental field to record daily air temperature and rainfall during growing period. Available nitrogen, phosphorus and potassium at the mentioned depth were 66.6 mg/kg, 14.2 mg/kg and 68.2 mg/kg, respectively. Soil pH was 7.2. No fertilizers were used during growth stages. Soybean and groundnut seeds mixed with rhizobia before plantation. The soybean density in monoculture was 10×60 cm with 1 seedling in each hole, which is equivalent to 167000 plants per ha. The groundnut density in monoculture was 20×60 cm with two seedlings in each hole, equivalent to 167000 plants per ha. The seed quantity of oat in monoculture was 200 kg/ha. In soybean and groundnut monoculture, the distance between two rows was 60 cm, and the distance between seedlings on the row was 10 cm and 20 cm, respectively. Oat seed rate per row for both monoculture and intercropping patterns were the same. In intercropping patterns, the distance between both groundnut and soybean row with oat rows were 20 cm. The ration of both soybean and groundnut intercropping with oat was 2:2. All seeds were sown by skillful workers on May 17th; furthermore, oat and legumes were harvested on 12th August and 7th September. Intercultural operations, such as weeding and plant protection, were done when required to ensure and maintain the normal growth of crop. The amount of nitrogen was determined by Kjeldahl analysis from dry and ground samples, and nitrogen was multiplied by 6.25 to determine protein content.

The relative total yield (RYT) is also used when both crops were sown on the basis of the same density and it can directly show the benefits of intercropping system. Competition index (CI) was measured as follows, where NA1 and NB1 was crop A and B per area, NA1 and NB1 were the production of A and B in intercropping pattern:

$$CI = \frac{(NA1 - NA)(NB1 - NB)}{NA \times NB}$$

The land equivalent ration (LER) and percentage of land saved (%) were calculated by using formula 1 and 2, respectively:

$$LER = (LER_a + LER_b) = \{(Y_{ab}/Y_{aa}) + (Y_{ba}/Y_{bb})\} \quad (1)$$

R of Oat = Yield of oat in intercropping/Yield of oat in single copping

R of Soybean= Yield of soybean in intercropping/Yield of soybean in single cropping

R of groundnut= Yield of groundnut in intercropping/Yield of groundnut in single cropping

$$\% \text{ Land saved} = 100 - 1/LER \times 100 \quad (2)$$

The percentage (%) land saved was used to assess the advantage of the intercropping system. All data were statistically treated using Analysis of variance (ANOVA) for randomized complete block design and the means were compared by Duncan's multiple

range method using SAS software program ($P \leq 0.05$).

RESULTS AND DISCUSSION

Seed yield significantly influenced by treatment (*Table 1*). The highest seed yield was related to sole cropping of soybean, which was 3263 kg/ha; moreover, it had no significant differences with soybean in intercropping of oat and soybean (TOS-S) and the one for groundnut in sole cropping (TG). Seed yield in TOS-S and TG was 3018.00 kg/ha, and 3071.00 kg/ha, respectively. Oat in the intercropping of oat and soybean had obtained the lowest amount of seed yield (832.3 kg/ha), followed by oat seed yield in intercropping of oat and groundnut (TOG-O), and oat seed yield in mono cropping (TO). There was not any significant difference in seed yield between oat yield in oat and soybean, and its yield in intercropping of oat and ground nut. However, oat seed yield in soybean and oat intercropping had significant differences with other treatments (*Table 2*). Some other researchers also stated that in intercropping system of cereal with a legume, forage yield is much higher than that of the legume sole crop is higher than that of the cereal sole crop (Mariotti *et al.,* 2009; Yolcu *et al.,* 2009).

Table 1 - Analysis of variance for seed yield in different cropping patterns

S.O.V	d.f.	Seed yield
Replication	3	50549.429
Treatment	6	3830576.286**
Error	18	170565.206

Ns: non-significant; *significant at 0.05 significance in F-tests; **significant at 0.001 significance in F-tests.

Table 2 - Mean comparison for seed yield (kg/ha) in different cropping patterns

Treatment	Seed yield (kg/ha)
TO	1708.00b
TOG-O	1208.00bc
TOS-O	832.3c
TS	3263.00a
TOS-S	3018.00a
TG	3071.00a
TOG-G	1851.00b

Common letters within each column do not differ significantly. TO means: sole cropping of oat; TOS-O: oat in the intercropping of oat and soybean; TOG-O: oat in the intercropping of oat and groundnut; TS: sole cropping of soybean; TOS-S: soybean in the intercropping of oat and soybean; TG: sole cropping of groundnut; TOG-G: groundnut in the intercropping of oat and groundnut.

The maximum protein percentage in ripening stage was achieved in soybean mono-cropping followed mono-cropping of groundnut and solo-cropping of oat, respectively. In intercropping treatments, the maximum and the minimum protein percentage was related to soybean in oat-soybean intercropping (13.35%), and in oat in oat-groundnut intercropping (8.95%), respectively. But, Li *et al.* (2009) reported that there were no significant differences in protein between intercropping and sole cropping. Legume-grain intercrops have produced higher seed and protein yields than pure grain crops (Jensen, 1996; Hauggaard-Nielsen *et al.*, 2001; Lauk & Lauk, 2005). The highest and the lowest amount of organic matter were related to soybean mono-cropping (17.36%), and oat mono-cropping (11.02%), respectively. Soybean in oat-soybean intercropping had obtained the maximum organic matter in ripening stage (18.18%), which had significant differences with oat in oat-groundnut and oat-soybean intercropping. However, it had no meaningful difference with groundnut in oat-groundnut intercropping (*Table 3*).

The highest pod number was related to soybean in mono-cropping, followed by intercropping of soybean and oat and mono-cropping of groundnut. The number of pod in mono cropping of soybean, intercropping of oat and soybean and mono cropping of groundnut was 49.75, 43.75, and 29, respectively. The lower pod number, which was 19.50 obtained for intercropping of oat and groundnut compare to those of other treatments (*Table 4*). There were not significant differences in number of seed per pod among treatments, in spite the fact that the maximum value for number of seed per pod was related to mono-cropping of groundnut and intercropping of oat and groundnut. The maximum and the minimum seed weight per pod were achieved for intercropping of oat and groundnut (1.47 g), and soybean mono-cropping (0.60 g). No significant difference was found in seed weight per pod between soybean mono-cropping, and intercropping of oat and soybean. Furthermore, there was no significant difference between groundnut mono-cropping and intercropping of oat and groundnut. Intercropping of oat and soybean had obtained the maximum seed weight per plant, which was 23.77 g. There were not any significant differences between soybean mono-cropping, intercropping of oat and soybean, and groundnut mono cropping. The minimum seed weight per plant was related to intercropping of oat and groundnut, which was 13.05 g. The higher value for a hundred seed weight was related to intercropping of oat and groundnut (42.50 g) than those of other treatments. After this treatment, the higher a hundred seed weight was related to groundnut mono-cropping, intercropping of oat and soybean, and soybean mono-cropping. Intercropping of oat and groundnut had significant differences with other treatments. In contrast, the difference in a hundred seed weight between soybean mono-cropping and intercropping of oat and soybean was not meaningful (*Table 4*).

Table 3 - Mean comparison for protein percentage (%) and organic matter (%) under different cropping patterns

Treatment	Protein percentage in booting stage	Organic matter in booting stage	Protein percentage in heading stage	Organic matter in heading stage	Protein percentage in grain filling stage	Organic matter in grain filling stage	Protein percentage in grain dough stage	Organic matter in grain dough stage	Protein percentage in ripening stage	Organic matter in ripening stage
TO	10.94b	14.87b	7.121c	9.690c	8.247c	11.22c	7.75c	10.52b	8.103c	11.02c
TOG-O	14.09b	19.16b	8.943bc	12.160bc	8.500c	11.57c	9.37bc	12.03b	8.950bc	12.17bc
TOS-O	16.15b	19.24b	9.280b	12.620bc	8.597c	11.69c	8.34c	11.35b	8.993bc	12.24bc
TG	19.72a	26.82a	15.790a	21.470c	16.55a	22.57a	12.69a	17.26a	8.907bc	12.11bc
TOG-G	19.65a	26.72a	15.720a	21.390c	15.73a	21.40a	13.13a	17.86a	11.24ab	15.28ab
TS	17.89a	24.33a	14.490a	19.170a	14.90ab	20.26ab	11.21ab	15.25a	12.76a	17.36a
TOS-S	20.95a	28.49a	14.410a	19.60a	13.12b	17.85b	11.82a	16.08a	13.36a	18.18a

Mean with the same letter in each column are not significantly different at 5% probability level.

Table 4 - Mean comparison for pod number, the number of seed per pod, seed weight per pod (g), seed weight per plant (g), and a hundred seed weight (g)

Treatment	Pod number	The number of seed per pod	Seed weight per pod (g)	Seed weight per plant (g)	A hundred seed weight (g)
TS	49.75a	3.00a	0.60b	23.38a	19.25c
TOS	43.75ab	3.00a	0.65b	23.77a	20.25c
TG	29.00bc	3.25a	1.32a	22.30a	41.00b
TOG	19.50c	3.25a	1.47a	13.05b	42.50a

Common letters within each column do not differ significantly. TS: soybean in mono cropping; TOS: intercropping of soybean and oat; TG: groundnut mono cropping; TOG: intercropping of oat and groundnut.

Although, the maximum plant height was obtained for oat in intercropping of oat and groundnut (93.25 cm), it had no significant differences with mono-cropping of oat, and soybean in intercropping of oat and soybean. The maximum and the minimum spike length was obtained for oat in intercropping of oat and groundnut (19.75 cm), and mono cropping of oat (17.50), which had no significant differences with each other. Indeed, soybean spike length in intercropping of oat and soybean had not significant differences with other treatments. The higher value of spikelet number obtained for oat in intercropping of oat and groundnut, followed by soybean in intercropping of oat and soybean, and oat mono-cropping, respectively. The differences between oat in intercropping of oat and groundnut was significant, however, oat mono-cropping and soybean in intercropping of oat and soybean had no meaningful difference with each other. Oat in intercropping of oat and groundnut obtained the maximum grain weight per plant, which was 1.40 g, and its differences with other treatments were significant. Oat mono-cropping had meaningful difference with soybean in intercropping of oat and soybean, but its difference with oat in intercropping of oat and groundnut was not significant. The maximum and the minimum a thousand seed weight were achieved in oat in intercropping of oat and groundnut and mono-cropping of oat. Oat in intercropping of oat and groundnut had significant differences with both treatments. In contrast, the difference between oat mono-cropping and soybean in intercropping of oat and soybean was not meaningful (*Table 5*). Legume-grain intercrops have produced higher seed yield components than pure grain crops (Jensen, 1996; Lauk & Lauk, 2008; Hauggaard-Nielsen *et al.,* 2006; Hauggard-Nielsen *et al.,* 2009).

Table 5 - Mean comparison for plant height (cm), spike length (cm), spikelet number, the number of grain per spike (g) and a thousand seed weight (g)

Treatment	Plant height	Spike length	Spikelet number	The number of grain per spike	Grain weight per plant	A thousand seed weight
TO	86.00a	17.50a	17.00b	36.50a	0.95ab	18.13b
TOG-O	93.25a	19.75a	24.50a	55.25b	1.40a	26.98a
TOS-S	89.50a	18.25a	18.25b	36.75a	0.82b	19.40b

Common letters within each column do not differ significantly. TO: sole cropping of oat. TOG-O: Oat in the intercropping of oat and groundnut. TOS-S: Soybean in the intercropping of oat and soybean.

R of oat in intercropping of soybean and oat, and intercropping of groundnut and oat were 0.49 and 0.70, respectively. R of soybean in intercropping of soybean and oat was 0.92. In intercropping of groundnut and oat, R of groundnut was 0.60. LER in all intercropping patterns, namely, intercropping of soybean and oat, and intercropping of groundnut and oat were higher than 1. LER in intercropping of soybean and oat, and intercropping of groundnut and oat were 1.41, and 1.30, respectively. LER above 1 means that a large area of land is needed to produce the same yield of sole crop of each component than with intercropping (Javanmard *et al.,* 2009; Soleymani *et al.,* 2012). LER and RYT more than one were mainly due to a greater ability to capture resources. Mohta & De (1980) reported that LER increased to maximum of about 48.0% by intercropping, compared with the cereal sole crops. Ghaderi *et al.* (2008) concluded that highest RYT shows the advantages of intercropping than sole cropping. Intercropping soybean with oat gave the highest LER value of 1.41, indicating that the greatest productivity per unit area was achieved by growing the two crops together than by growing them separately. An LER of 1.0 shows that intercropping produces the same yields as of sole cropping, and above 1.0 giving greater yields than sole crops (Arshad & Ranamukhaarachchi, 2012). Higher LER in intercropping treatments indicated yield advantage over mono-cropping due to better land utilization (Nasrollahzadeh *et al.,* 2009). In agreement with the results of this trial, many scientists also reported that LER is greater than one in cereal and legume intercrops (Ghosh, 2004; Yildirim & Guvenc, 2005). With these LER values, 29.07% and 23.07% of land were, respectively, saved in intercropping of soybean and oat, and intercropping of groundnut and oat, respectively, which could be used for other agricultural purposes. In both intercropping of soybean and oat, and intercropping of groundnut and oat, CI were less than 1, which means that both these two intercropping patterns have positive effects (*Table 6*).

Table 6 - R of oat, soybean and groundnut, LER, RYT, land saved (%) and competition index (CI) for intercropping patterns

Intercropping pattern	R oat	R soybean	R groundnut	LER	RYT	Land saved (%)	Competition index (CI)
Soybean and oat	0.49	0.92	-	1.41	1.41	29.07	0.67
Groundnut and oat	0.70	-	0.60	1.30	1.30	23.07	0.67

LER= land equivalent ration; RYT= relative yield total.

CONCLUSION

Using cereals intercropped with legumes improves the value of farming system, moreover, the selection of appropriate intercropping system remains the best approach. Moreover, mixing species in cropping systems may lead to a range of benefits that are expressed on various space and time scales, from a short-term increase in crop yield and quality, to long-term increase in crop yield and quality, to long-term agro-ecosystem sustainability, up to societal and ecological benefits. The highest seed yield was obtained for mono-cropping of soybean, followed by mono-cropping of groundnut and oat. Oat seed yield intercropping of oat and groundnut, and intercropping of oat and soybean were 1208.00 kg/ha, and 832.3 kg/ha, respectively. The highest grain yield was obtained when soybean was grown together with oat, where the higher yield of intercrop is due to the better usage of nutrient, water and light. LER in all intercropping patterns were higher than 1. LER in intercropping of soybean and oat, and intercropping of groundnut and oat were 1.41, and 1.30, respectively. With these LER values, 29.07% and 23.07% of land were, respectively, saved in intercropping of soybean and oat, and intercropping of groundnut and oat, respectively, which could be used for other agricultural purposes. In both intercropping of soybean and oat, and intercropping of groundnut and oat, CI were less than 1, which means that both these two intercropping patterns have positive effects. Using cereals intercropped with legumes improves the value of farming system, moreover, the selection of appropriate intercropping system remains the best approach. This information can help in the adaptation of oat- Intercrops for increased forage production in new cropping systems.

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