doi:10.14720/aas.2018.111.1.04 Original research article / izvirni znanstveni članek

# Changes in dry matter, protein percentage and organic matter of soybean-oat and groundnut-oat intercropping in different growth stages in Jilin province, China

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Received March 30, 2017; accepted January 26, 2018.
Delo je prispelo 30. marca 2017, sprejeto 26. januarja 2018.

**ABSTRACT**

One of the most important and sustainable cropping practice is intercropping. 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 mono-cropping systems, oat mono-cropping obtained the highest dry matter and nitrogen accumulation in all growth stages. The maximum protein percentage in all stages except for ripening stage, were for groundnut mono-cropping. Although, the maximum organic matter in ripening stage was achieved in mono-cropping of soybean, the highest one in other stages was related to groundnut mono-cropping. In intercropping patterns, oat in oat-groundnut 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. Furthermore, 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. This information can help in the adaptation of oat- intercrops for increased forage production in new cropping systems.

**Key words:** protein percentage; organic matter; soybean; groundnut; oat; intercropping

**IZVLEČEK**

**SPREMEMBA SUŠINE, ORGANSKE MASE IN VSEBNOSTI BELJAKOVIN V VMESNIH POSEVKIH SOJE, OVSA IN ARAŠIDOV V RAZLIČNIH FAZAH RAZVOJA IN RASTI V PROVINCI JILAN, KITAJSKA**

Eden najpomembnejših ukrepov za trajnostni način pridelave poljščin je vmesna setev. V raziskavi je bil izveden popolni naključni poljski poskus s štirimi ponovitvami na suhih peščenih tleh v Horkinu, območje Baicheng, v provinci Jilin v severni Kitajski, leta 2011. Obravnavanja so obsegala različne načine setve v čistem posevku in v vmesnem posevku, in sicer: čisti posevek ovsa (TO); setev ovsa v vmesnem posevku s sojo (TOS-O); setev ovsa v vmesnem posevku z arašidi (TOG-O); čisti posevek soje (TS); setev soje v vmesnem posevku z ovsom (TOS-S); čisti posevek arašidov (TG); arašidi v vmesnem posevku z ovsom (TOG-G). Pri setvi čistih posevkov je imel čisti posevek ovsa največjo vsebnost suhe mase in dušika v vseh razvojnih fazah. Največji odstotek beljakovin je bil v vseh fazah razvoja, z izjemo faze zorjenja, v čistih posevkih arašidov. Največja vsebnost organske mase je bila v čistih posevkih soje dosežena v fazi zorenja, v drugih razvojnih fazah pa v čistih posevkih arašidov. V vmesnih posevkih je imel posevek ovsa z arašidi največjo vsebnost suhe mase v vseh fazah rasti in razvoja. Največji odstotek beljakovin in vsebnost organske snovi v fazah latenja, polnjenja zrnja in fazi voščene zrelosti zrnja sta bila dosežena v sistemu setve arašidov z medsetvijo arašidov z ovsom. Največji vsebnosti beljakovin in organske mase v fazah kolenčenja in zorenja sta bili doseženi v vmesnih posevkih soje z ovsom. Rezultati raziskave jasno nakazujejo, da setev ovsa v vmesnem posevku z arašidi vpliva na rast posameznih poljščin v mešanicah kot tudi na pridelek suhe mase in odvzem dušika. Pridobljene izkušnje lahko pomagajo prilagoditvam vmesnih posevkov z ovsom za povečanje pridelave krme v novih načinih pridelave.

**Ključne besede:** vsebnost beljakovin; sušina; organska masa; soja; arašidi; oves; vmesna setev

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## 1 INTRODUCTION

Intercropping, the mixed growth of two or more crops, is practiced in more than 28 million hectares of areas sown annually in China. Multiple-cropping systems in China, including intercropping and related practices, have contributed to increased crop productivity due to a more effective utilization of resources compared to monoculture crops (Karimuna et al., 2012).Cereal-legume intercropping system was experimented by many researchers in all over the world (Carr et al., 2004; Lithourgidis et al., 2006; Lauk and Lauk, 2008; Li et al., 2009; Soleymani et al., 2011; Soleymani et al., 2012). The benefits of oat intercropping with other crops are also reported by many researchers (Malezieus et al., 2009; Naumann et al., 2010; Gong et al., 2011; Han et al., 2012). Researchers also reported the improvement of peanut production in intercropping system (Justino and 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). On the one hand, monocultures of legumes and cereals do not provide satisfactory results for forage production (Soleymani et al., 2011; Soleymaniand Shahrajabian., 2012). On the other hand, small grain cereals provide high yield in terms of dry mass but they produce forage with low protein content (Lauk and Lauk, 2008). Other benefits of mixtures include greater uptake of water and nutrients, enhanced weed suppression, and increased soil conservation (Li et al., 2009). These systems also protect soil against erosion, improve the use of limited resources, improve forage quality, increase stability of yield and provide higher returns (Javanmard et al., 2009; Lee and Yoon, 2013). Intercropping of legumes with non-legumes results in production of more dry matter and an increase in protein content of the resulting crop, with minimum N fertilizer input (Ijoyah and Fanen, 2012).Caballero and Goicoechea (1986) reported that the most suitable cereal for mixtures with legume is oat (*Avena sativa* L.). Soybean (*Glycine max* (L.) Merrill), which is one of the major legume crops produced worldwide (Garrett et al., 2013; Jing and Chin, 2013; Mazza et al., 2013), is commercially used for its edible oil, proteins, health functional ingredients, and fermented food (Jensen, 1996; Sharma et al., 2013). Materials left after evaporation is the dry matter, while loss in weight upon ignition at certain defined temperature is the organic matter content. This research had three aims. The first was to study the organic matter production in mono-cropping and intercropping patterns. The second aim was to evaluate nitrogen and protein percentage for each treatment. The third aim was to study changes of dry matter in different stages of oat intercropped by soybean and groundnut.

## 2 MATERIALS AND METHODS

The study was conducted under field conditions in the arid Horqine sandy land in Baicheng District (44$^o$14$^/$-46$^o$18$^/$N, 121$^o$38$^/$-124$^o$22$^/$E), Jilin Province, Northern China in 2011. A randomized complete block design with four replications was used. Treatments comprised different mono cropping and intercropping patterns, TO: sole cropping of oat (*Avena sativa* 'Baiyan2'), TOS-O: oat in the intercropping of oat and soybean (*Glycine max* 'Zao Shu96136'), TOG-O: oat in the intercropping of oat and groundnut (*Arachis hypogaea* 'Baiyuanhual'), TS: sole cropping of soybean, TOS-S: soybean in intercropping of oat and soybean, TG: sole cropping of groundnut, TOG-G: groundnut in the intercropping of oat and groundnut. No nitrogen fertilizer was used in this research. 55 kg ha$^{-1}$ $P_2O_5$, 45 kg ha$^{-1}$ $K_2O$, 4.5 kg ha$^{-1}$ $FeSO_4$, 1 kg ha$^{-1}$ $H_3BO_3$, 1.5 kg ha$^{-1}$ $Na_2MOO_4.2\ H_2O$ 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$^{-1}$, 14.2 mg kg$^{-1}$ and 68.2 mg kg$^{-1}$, respectively. Soil pH was 7.2. No additional fertilizers were used during growth stages. Soybean and groundnut seeds were mixed with rhizobia before plantation. The soybean density in monoculture was 10 × 60 cm with 1 seedling in each hole, which is equivalent to 167 thousand plants per ha. The groundnut density in monoculture was 20 × 60 cm with two seedlings in each hole, equivalent to 167 thousand plants per ha. The seed quantity of oat in monoculture was 200 kg ha$^{-1}$. 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 12$^{th}$ August and 7$^{th}$ 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. (Pregl, 1945). Dry matter was determined by drying samples for 15 h at 105 $^{o}$C; dry matter was expressed as a percentage of the sample at the time of the analysis. Organic matter was determined by ashing for at least 4 h at 500 $^{o}$C. 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 ($P \leq 0.05$).

## 3 RESULTS AND DISCUSSION

### 3.1 Booting stage

There was no significant difference in nitrogen concentration among cropping patterns. Oat dry matter in booting stage in oat-soybean intercropping was higher than oat yield in oat-groundnut intercropping and other treatments, which had significant differences with other treatments. The maximum nitrogen accumulation in booting stage was also obtained for oat in intercropping of oat and soybean (Table 1). Protein percentage of soybean in oat-soybean intercropping obtained the maximum value (20.95 %). The highest value of organic matter was obtained for soybean in oat-soybean intercropping, followed by ground nut in oat-groundnut intercropping and oat in oat-soybean intercropping. Moreover, there was not any significant difference in organic matter of oat in both oat-groundnut and oat-soybean intercropping. In mono-cropping, the maximum organic matter in booting stage was achieved for groundnut mono-cropping (26.82 %) (Table 3). Using cereals intercropped with legumes improves the value of farming systems, moreover, the selection of appropriate intercropping system remains the best approach (Soleymani and Shahrajabian, 2012).

### 3.2 Heading stage

In solo-cropping patterns, the highest dry matter in heading stage was obtained for oat mono-cropping, followed by soybean and groundnut mono-cropping. On the one hand, there was no significant difference in dry matter and nitrogen accumulation between dry matter of oat in oat-groundnut and oat-soybean intercropping. In the other hand, oat in oat-groundnut obtained the highest value of dry matter and nitrogen accumulation (Table 1). Mono-cropping of groundnut obtained the maximum value of protein percentage (15.79 %) and organic matter (21.39 %). Groundnut in oat-groundnut intercropping had obtained the maximum value of protein percentage in heading stage, which had significant differences with oat in both oat-soybean and oat-groundnut intercropping; however, its difference with soybean in oat-soybean intercropping was not significant. Crude protein concentration of forage is one the most important criteria for forage quality evaluation (Dordas and Lithourgidis, 2011). Organic matter value of groundnut in oat-groundnut intercropping (21.39 %) in heading stage was significantly higher than in other intercropping treatments. Furthermore, the difference in organic matter of oat in both oat-soybean and oat-groundnut intercropping was not meaningful (Table 3).

### 3.3 Grain filling stage

In mono-cropping patterns, the highest value of dry matter was obtained for oat, followed by soybean and groundnut. In intercropping patterns, the highest and the lowest dry matter production was related to oat yield in oat-groundnut intercropping, and groundnut in oat-groundnut intercropping. 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 and forage quality is higher than that of the sole cereal crop (Mariotti et al., 2009; Dordas et al., 2012).The maximum nitrogen accumulation in grain filling stage was achieved in oat mono-cropping, which had significant differences with groundnut and soybean mono-cropping. Oat nitrogen accumulation in oat-groundnut intercropping, which had no meaningful difference with nitrogen accumulation of oat in oat-soybean, obtained the highest value of it (Table 1). The maximum value of protein percentage (16.55 %) and organic matter in grain filling stage (22.57 %) was related to groundnut mono-cropping. Protein percentage for groundnut in oat-groundnut intercropping was higher than those of other treatments. There were significant differences between groundnut in oat-groundnut intercropping and other intercropping patterns in the term of protein percentage. Indeed, there was no significant difference in organic matter for oat in oat-groundnut intercropping and oat in oat-soybean system (Table 3).

### 3.4 Grain dough stage

The highest production of dry matter and nitrogen accumulation in grain dough stage was obtained for oat mono-cropping. The highest amount of dry matter in grain dough stage was achieved in oat in oat-groundnut intercropping in comparison with those of other intercropping systems; moreover, its differences with other treatments were significant. Oat nitrogen accumulation of oat in oat-groundnut intercropping obtained the maximum value, which had meaningful differences with other treatments. In contrast, nitrogen accumulation for groundnut in oat-groundnut intercropping, which obtained the minimum value, had no significant difference with the one for soybean in oat-soybean intercropping (Table 2). Groundnut mono-cropping obtained both the maximum protein percentage (12.69 %), and organic matter (17.26 %), followed by soybean mono-cropping and oat mono-cropping, respectively. Among intercropping patterns, the maximum protein percentage and organic matter production was achieved in groundnut in oat-groundnut intercropping, which had no significant difference with the value of soybean in oat-soybean intercropping. Indeed, differences between oat in oat-groundnut and oat-soybean intercropping were not significant (Table 3). Ghanbari-Bonjar and Lee (2003) and Arshad and Ranamukhaarachchi (2012) concluded that intercropping had greater total output for protein content compared to sole cropped of crops.

### 3.5 Ripening stage

In solo-cropping, the highest dry matter in grain filling stage was related to oat mono-cropping, followed by mono-cropping of soybean and groundnut mono-cropping. On the one side, higher values of nitrogen accumulation were related to oat in oat-groundnut intercropping than those of other intercropping treatments. On the other side, the difference in oat yield in oat-groundnut and oat-soybean was not meaningful (Table 2). The maximum protein percentage in ripening stage was achieved in soybean mono-cropping followed by 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 content between intercropping and sole cropping. Legume-cereal intercrops have produced higher seed and protein yields than pure cereal crops (Jensen, 1996; Hauggaard-Nilsen et al., 2001; Lauk and 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 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).

**Table 1:** Mean comparison for nitrogen concentration (g $g^{-1}$ dry matter), dry matter (g $m^{-2}$) and nitrogen accumulation (g $m^{-2}$) in booting stage, heading stage and grain filling stage under different cropping patterns

| | Booting stage | Booting stage | Booting stage | Heading stage | Heading stage | Heading stage | Grain filling stage | Grain filling stage | Grain filling stage |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | Nitrogen concentration in booting stage | Dry matter in booting stage | Nitrogen accumulation in booting stage | Nitrogen concentration in heading stage | Dry matter in heading stage | Nitrogen accumulation in heading stage | Nitrogen concentration in grain filling stage | Dry matter in grain filling stage | Nitrogen accumulation in grain filling stage |
| TO | 0.017a | 73.53c | 1.283b | 0.011a | 149.7b | 1.710b | 0.012a | 205.7b | 2.703b |
| TOG-O | 0.022a | 99.83b | 1.273a | 0.013a | 232.2a | 3.327a | 0.013a | 312.9a | 4.251a |
| TOS-O | 0.022a | 107.8a | 2.443a | 0.014a | 209.5a | 3.103a | 0.013a | 284.6a | 3.913a |
| TG | 0.031a | 2.400d | 0.076c | 0.024a | 6.233c | 0.156c | 0.026a | 11.27c | 0.296c |
| TOG-G | 0.031a | 1.833d | 0.053c | 0.024a | 6.400c | 0.163c | 0.024a | 10.53c | 0.263c |
| TS | 0.028a | 7.100d | 0.200c | 0.022a | 10.07c | 0.233c | 0.023a | 22.60c | 0.543c |
| TOS-s | 0.033a | 4.300d | 0.143c | 0.022a | 8.133c | 0.183c | 0.020a | 19.53c | 0.406c |

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

**Table 2:** Mean comparison for nitrogen concentration (g $g^{-1}$ dry matter), dry matter (g $m^{-2}$) and nitrogen accumulation (g $m^{-2}$) in grain dough stage and ripening stage under different cropping patterns

| | Grain dough stage | Grain dough stage | Grain dough stage | Ripening stage | Ripening stage | Ripening stage |
|---|---|---|---|---|---|---|
| Treatment | Nitrogen concentration | Dry matter | Nitrogen accumulation | Nitrogen concentration | Dry matter | Nitrogen accumulation |
| TO | 0.012a | 292.5b | 3.610b | 0.012a | 246.3c | 3.187c |
| TOG-O | 0.014a | 333.8a | 5.003a | 0.014a | 345.3a | 4.953a |
| TOS-O | 0.013a | 292.9b | 3.880b | 0.014a | 303.7b | 4.370b |
| TG | 0.019a | 26.17c | 0.530c | 0.013a | 30.10d | 0.430e |
| TOG-G | 0.020a | 16.73c | 0.350c | 0.017a | 19.37d | 0.346e |
| TS | 0.017a | 37.30c | 0.660c | 0.019a | 43.13d | 0.880d |
| TOS-S | 0.018a | 27.63c | 0.520c | 0.021a | 44.50d | 0.950d |

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

**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 percent probability level.

## 4 CONCLUSION

Using cereals intercropped with legumes improves the value of farming systems, 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 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. This information can help in the adaptation of oat-intercrops for increased forage production in new cropping systems.

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