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Effects of wheat/alfalfa intercropping on soil nutrients

ZHANG Xiao-hong[1]*, DING Heng [2], ZHOU Zheng-xiao[2], HE Ya-nan[1]
[1]College of Geographical Science, Shanxi Normal University, Linfen China, 041000
[2]Linfen Weather Bureau, Linfen China, 041000

***Corresponding Author**
Name: ZHANG Xiao-hong
Email: jiaoxuekeyan@163.com

Abstract: Soil organic matter, pH and nitrogen, phosphorus and potassium nutrients content and distribution characteristics on 2m depth profile of wheat, alfalfa and wheat /alfalfa intercropping was measured and analyzed through field experiment. Each treatment had a profile of soil organic matter distribution as S shape. The surface layer of 0-20cm soil organic matter content of XD (20g / kg) is slightly higher than the other two treatments; 0-60cm soil organic matter content ranked as XD> XMT> MD, while deep layer organic matter content of XMT was over XD (60-100cm) and MD (150-200cm), which may be convincing to the fact that alfalfa, described as a strong crop of deep roots, was further promoted down deeply roots distribution after intercropped with wheat. Soil pH value increased with depth deeper, the whole body is alkaline, and there was no significant difference between treatments. 0-20cm surface of treatments did not differ significantly in the total nitrogen content, while within 20-60cm soil depth MD and XMT's total nitrogen content were significantly higher than XD's; underlying XD's available nitrogen accounted for 1/4 of profile. Wheat intercropping with alfalfa can not only help to improve the depth of 20-150cm soil nitrogen fertility, but also relief the problem of nitrogen loss at the bottom of wheat field. After a period of wheat consumption, XMT and XD surface soil available phosphorus content processing close 10 mg/kg, MD only 6.4210 mg/kg. Wheat/alfalfa intercropping system can optimized the whole long section of soil potassium consume ratio, so it can be applied less even no Potassium Fertilizer.
Keywords: Wheat, Alfalfa, Intercropping, Soil Nutrients

INTRODUCTION

Known as "the king of the grass", alfalfa has great effect in improving crops for rotation, controlling plant diseases and insect pests, perfecting soil physical properties [1-3] to provide high quality forage and protect the ecological environment [4-7]. So to interplant alfalfa and winter wheat sure has a very big prospect in helping ease the competition for field between grain and pasture, contributing to agriculture and stock farming win-win [8]. We once had research reports for the significant economic benefit of wheat and alfalfa intercropping [9-10]; In Kezheng Ma's results recently also showed that intercropped system of wheat and alfalfa significantly increase the wheat yield by optimizing the natural enemy combination of Allothrom bium ovatum, lady beetle and parasitic wasp, which raised the controlling effect on macrosiphum avenae, the main pest of wheat [11]. Xiaobin Zhang conducted wheat / alfalfa intercropping biological pot experiment to study the effect of phytoremediation of PAHs contaminated soil, repair risk assessment and agricultural utilization after the soil remediation [12]. But currently as a whole, within the scope of our country and even the worldwide, for the study of Inter Cropping of wheat and alfalfa it is not enough with mainly focusing on crop yield, economic benefit and phytoremediation analysis [13-15], especially rare on soil nutrients in the process of intercropping. Therefore the theses systematically investigated the influences of wheat interplanting with alfalfa under the condition of field production on main soil nutrients, based on the experiment in Yaodu District of Linfen City, in order to provide reference basis for the progress and promotion of planting technology in wheat/alfalfa intercropping.

MATERIALS AND METHODS

Experiment situation

Test area is located in Dong Du village, Yaodu District of Linfen City (35°55′N, 111°34′E; 484 meters above sea level). It is a warm temperate semi-arid continental monsoon climate, with an average annual precipitation of 550 mm, average temperature 9~13℃ and frost free period about 203 days, belonging to the dry farming area. The soil type is cinnamon soil. The basic properties of soil in the experiment field are shown in table1 (basic soil samples were taken before wheat seeding).

Table 1: Soil nutrients of experimental site

Soil layer (cm)	pH	Organic matter (g /Kg)	Total N (g /Kg)	Total P (g /Kg)	Total K (g /Kg)	Available Nitrogen (mg /Kg)	Effective Phosphoric (mg /Kg)	Available Potassium (mg /Kg)
0～20	8.05±0.40	21.51±1.07	1.18±0.06	0.60±0.03	20.85±1.04	53.82±2.69	10.59±0.53	235.55±11.75

Experimental materials and design

Test planting wheat variety for Jin Mai 95, Alfalfa for local variety, and both were bought from Seed Company in the county town. Among them, the 1000 grain weight of alfalfa was 2.255 g, the germination rate was 75%, and that of the half winter wheat variety Jin Mai 95 was 40 g and 65%.

Field experiment consisted of three treatments of single seeding for wheat (XD) and alfalfa (MD) and wheat/alfalfa intercropping (XMT). Every treatment was duplicated three times to form a total of nine experimental plots, of which the area was 50 square meters and randomly arranged. Alfalfa was planted in April 2014, north-south direction sowing in line with 40 cm row spacing and the seeding rate of 18 kg per hectare; winter wheat was sowed in late September on the established alfalfa field by mechanical seeding in the same direction, with the 18cm row spacing and seeding quantity of 225kg/ hectares. Compound fertilizer was ground broadcasted before the mechanical sowing of wheat in autumn (N 187.5 kg/hm^2, P_2O_5 97.5 kg/hm^2, K_2O 52.5 kg/hm^2); additional fertilizer was applicated at wheat standing stage in spring for ground topdressing (N 225 kg/hm^2, K_2O 37.5 kg / hm^2) with artificial soil coverage.

Soil sample collection and measuring

Soil sample collection and handling

Soil samples were collected in early June of 2015, after wheat harvest in each experimental plot, with ***s*** type distribution of 5 drillings for disjunctive 0~20 cm 、20~60 cm、60~100 cm、100~150 cm and 150~200 cm a total of five levels each. Fully mixed the hierarchical samples and had a quarter of sample-retention, which was placed indoor for natural air drying, then excluded the large stones, plant roots and other impurities to be grinded and through 20 and 60 mesh nylon sieve, bag sealing for soil total and available nutrients analysis.

Assay methods for soil nutrients determination [16]

- Soil Organic Matter: Volumetric method of oil bath - heated potassium dichromate oxidation
- Soil Total Nitrogen: Kjeldahl distillation
- Soil Total Phosphorus: Sodium hydroxide melting - molybdenum antimony colorimetric method
- Soil Total Potassium: Alkali fusion - flame photometer or atomic absorption spectrophotometer method
- Soil available nitrogen: Alkali solution diffusion method
- Soil available Phosphorus: Sodium bicarbonate extract - molybdenum antimony colorimetric method
- Soil available potassium: Ammonium acetate extraction - atomic absorption spectrophotometer method
- Soil pH: Potentiometric method

Statistical analysis of data

The data of the experiment were analyzed for the analysis of variance and significance in the SPSS statistical analysis software, combined with Excel 2013.

RESULTS

Effects of wheat and alfalfa intercropping on soil organic matter and pH

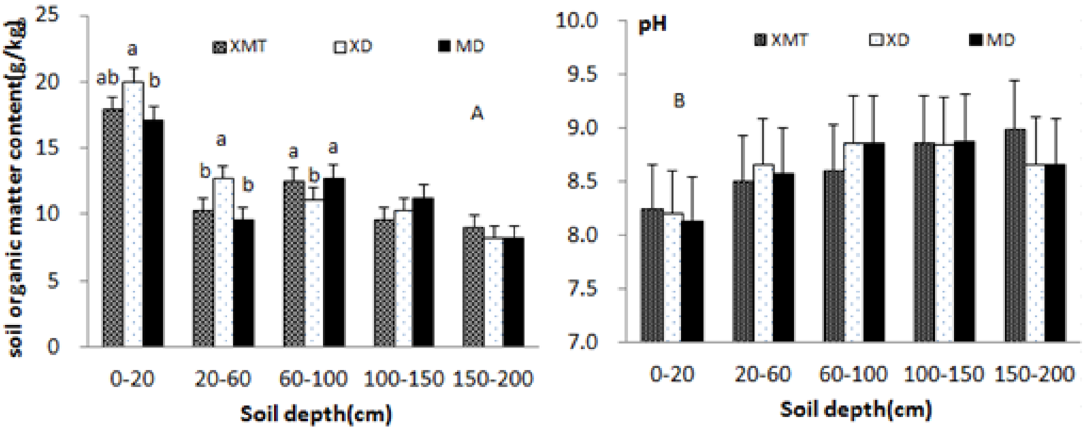

Fig 1: Soil organic matter content（A）and pH（B）of different treats in 5 depths

Note: different letters represent at $P < 0.05$ significance between treatments. XD means monoculture of wheat, MD means monoculture of Alfalfa and XMT means the intercropping of wheat/alfalfa (the same below)

For the soil organic matter determination results of different depth (Figure 1, A), both monocultures and intercropping of wheat and alfalfa have the highest soil organic matter content in topsoil (0 ~ 20 cm), with an average of 18.87g/kg, which belongs to the organic matter ⅳ according to the national second time soil survey grading standards [17] ; the deepest soil organic matter contents were lowest (average 8.07g/kg) but also reached grade Ⅴ. Above 60 cm the soil organic matter content of XD was significantly higher than that of MD, while with the increase of the depth this trend reversed. It is closely related with the biomass distribution of wheat and alfalfa. From the root system distribution characteristics, 85% of the wheat root distributes within 100 cm soil depth, 0-50 cm accounted for more than 60% [18]; alfalfa belongs to deep root crops, with whose roots in the second year reach to a depth of up to 2 m, 0~50 cm account for only 50% and 150 cm depth of root amount as high as 15% [19]. Furthermore, aboveground biomass is the main factor affecting the content of organic matter in the surface. Due to the implementation of wheat straw mulching and alfalfa harvested timely, hence intercropping wheat and alfalfa reduced the quantity of wheat straw production and returning, and alfalfa helped increasing deep underground biomass ratio. All this resulted in 0-60 cm soil organic matter content ranking as XD>XMT>MD, while deeper XMT organic matter content was more than that of XD (60~100 cm) and MD (150~200 cm).

Unlike the trend of organic matter change, Soil pH values increased with depth and were all alkaline entirely (Figure 1 B). The average value of surface was 8.2, which was declined slightly compared with that of the beginning of the experiment; that of deeper layer was 8.7~8.8. There were no significant differences among the three treatments.

Effects of wheat and alfalfa intercropping on soil available nutrients

Soil alkali-hydrolyzable nitrogen also called effective nitrogen, including inorganic nitrogen (ammonium nitrogen, nitrate nitrogen) and hydrolysis of organic nitrogen (amino acids, amides and easy hydrolysis protein). It is closely related with crop growth and can reflect the soil nitrogen supplying in the near future. From the different depth of soil available nutrient determination results (Fig. 3-N) we can learn that the surface (0-20 cm) alkali-hydrolyzable nitrogen content of XD and MD were at the lower levels, but the values increased by 18% and 38% compared with that before wheat sowing; while that of XMT（25mg/kg） declined by 53%. The surface available nitrogen in XD and MD increased with spring Topdressing on and also is related to the nitrogen fixation of alfalfa; the reduced available nitrogen in XMD may indicate that wheat and alfalfa intercropping strengthened nitrogen absorption and utilization ability of superficial roots. In contrast at the downward 20~100 cm depth, the content of Soil alkali-hydrolyzable nitrogen in XMT reached fifth grade (30-60mg/kg [17]), but that of XD and MD were reduced to sixth (<30mg/kg [17]). At 100~150 cm three treatments were up to five levels and sorted as MD>XMT>XD; in 150~200 cm the range was XD >MD>XMT, of which the XMT was down to the lowest level.

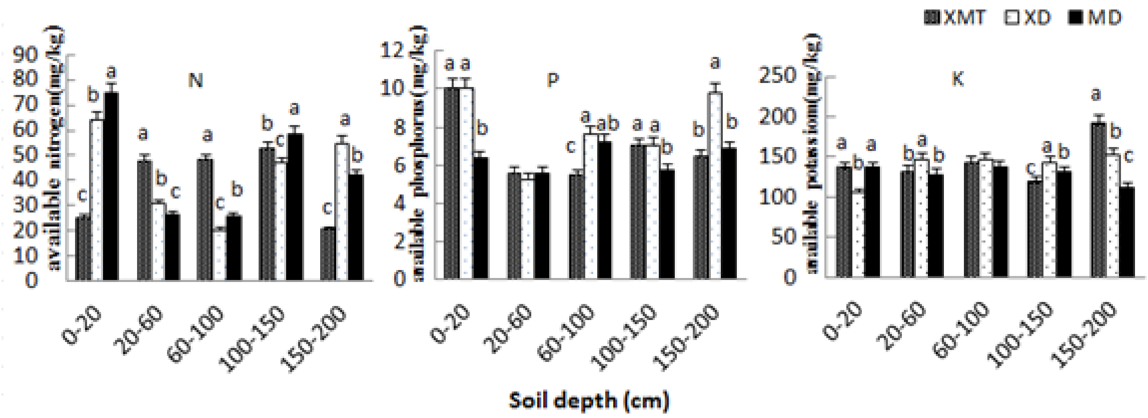

Fig 2: Soil available nutrients content of different treatments in 5 depths

After a season of wheat consumption, XMT and XD had a similar surface soil available phosphorus content (10mg/kg), which assumed to be lack of phosphorus both for wheat and alfalfa [20, 21] (Fig. 3-P) .The deep soil available phosphorus contents of the three treatments were basically low as 6-8 mg / kg, and that of MD was full-bodied below 7mg/kg. At the two deep depths of 60~100 cm and 150~200 cm XMT had significantly lower soil available phosphorus than XD; but compared with MD, it was in like manner only on the previous depth level, and not significant on the latter. The results implied that application of phosphate fertilizer in production practice will be both necessary and significant for the three treatment modes.

In 0-20 cm the soil available potassium content of XD (104 mg/kg) was significantly lower than that of MD and XMT, and the latter two almost equal (136 mg/kg). Although the three treatments' soil available potassium contents dropped substantially when compared with the start of wheat season (40-50%), it still belonged to better than average level for the growth demand of wheat and alfalfa [20-22]. From 20cm down to 150 cm the available K contents in the three treatments had little difference, roughly in the range of 120 ~ 150 mg/kg, which was in potassium surplus state. At the bottom of 150~200cm the soil available potassium of XMT and XD were reached a very high level (191 mg/kg and 153 mg/kg respectively), even with the relatively low level of MD was as high as 111 mg/kg.

Effects of wheat and alfalfa intercropping on soil total nutrients

The results of soil total nutrients of the three treatments with different depth were shown in table 2. There was no significant difference in the contents of total nitrogen in the surface layer of 0~20 cm; the total phosphorus was significantly different and the order was XMT>XD>MD; the total potassium content was MD>XMT>XD, but the difference between XMT and XD not significant. At 20~60 cm depth soil total nitrogen of XMT and MD were significantly higher than that of XD, while the total phosphorus of XD and XMT were significantly higher than MD, and there was no significant difference among the three in total potassium content. At the depth of 60~100 cm, the total nitrogen content of XMT was significantly higher than that of XD and extremely higher than that of MD; total phosphorus contents were significantly different with a rank of MD>XMT>XD; there was no significant difference in total potassium content between MD and XMT, but both were significantly higher than XD. At 100~150 cm depth, the differences of total nutrients with the three treatments were highly significant, ranked as XMT>XD>MD for total nitrogen, MD>XMT>XD for total phosphorus and MD>XD>XMT for total potassium content. At the bottom layer the differences of total nutrients among the treatments also reached significant level, some even reached extremely significant level, and the rank of total nitrogen was MD>XD>XM, of total phosphorus MD>XMT>XD and of total potassium MD>XMT>XD.

Table 2: Soil total nutrients content of different treats in 5 depths (g/kg)

		Soil depths (cm)				
Items	Treatments	0-20	20-60	60-100	100-150	150-200
Total nitrogen	XD	1.13±0.55	0.48±0.03B	0.56±0.03b	0.48±0.03B	0.36±0.02b
	MD	1.11±0.55	0.66±0.04A	0.52±0.03B	0.27±0.01C	0.41±0.02Aa
	XMT	1.11±0.55	0.64±0.04A	0.62±0.03Aa	0.56±0.03A	0.31±0.01Bc
Total pho -sphorus	XD	0.63±0.03B	0.71±0.04A	0.54±0.02C	0.71±0.04C	0.73±0.04Bc
	MD	0.52±0.02C	0.67±0.03A	0.82±0.04A	1.09±0.06A	0.96±0.05Aa
	XMT	0.79±0.04A	0.47±0.02B	0.67±0.03B	0.85±0.04B	0.86±0.04Ab
Total po -tassium	XD	17.48±0.88B	20.38±1.02	17.67±0.89B	20.32±1.01b	23.05±1.16b
	MD	24.68±1.23A	20.70±1.03	23.08±1.16A	22.99±1.15Aa	27.37±1.37Aa
	XMT	18.56±0.93B	21.33±1.07	21.89±1.09A	16.89±0.85Bc	21.30±1.07Bb

Note: different capital letters in the same lines represent at $P < 0.01$ significance, lowercase letters at $P < 0.05$

CONCLUSIONS

The profile distribution of soil organic matter in 2 m deep soil was S type. Compared to wheat, alfalfa has the advantage of increasing soil organic matter in addition to the function of nitrogen fixation. After intercropped with alfalfa, the surface organic matter content decreased with the decrement of the amount of wheat straw returned to the ground; but in the deeper layer, wheat could promote alfalfa roots distributing downward deeply so that significantly increase the content of organic matter in deep soils.

The distribution of total nitrogen and available nitrogen content was closely related to soil organic matter. In the wheat/alfalfa intercropping system, at surface soil layer after a season of wheat consumption the level of available nitrogen was significantly reduced due to the fact that the presence of alfalfa promoted wheat's absorption of nitrogen utilization. Although it was enough for alfalfa growth in later period, it is in very low level of nitrogen deficiency for summer maize production. So it needs to supplement of nitrogen if there was a next planting of summer maize still. But Intercropping of wheat and alfalfa was conducive to improve the deep soil nitrogen fertility, and also helpful to avoid the conventional nitrogen loss problems in the bottom of wheat field.

In the growth process of alfalfa phosphorus element consumption was great, especially in the surface soil; intercropping of wheat and alfalfa increased phosphorus activity (fertility) of root layer soil but also increased the phosphorus consumption. So in the production practice of this planting system to applicate phosphorus fertilizer for the production security is critical. Although for alfalfa the consumption of soil potassium at surface layer was also tremendous, the wheat/alfalfa intercropping system could optimize soil potassium consumption ratio on the whole profile, so potassium fertilizer can be less used or even not.

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