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Soil Fertility Evaluation of Wheat /Alfalfa Intercropping

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Abstract **Original Research Article**

Perfect evaluation of soil fertility is the basis of constructing crop fertilization scheme. In this paper, principal component analysis, systematic cluster analysis and diagnosis of soil nutrient abundance-deficiency were used to evaluate the soil fertility of wheat/alfalfa intercropping system. The results of soil fertility evaluation showed that the soil fertility of wheat/alfalfa intercropping was higher than that of exclusive alfalfa, but lower than single wheat's. Diagnosis of soil nutrient abundance-deficiency indicate that the soil total nitrogen and available nitrogen were deficient, the soil total potassium and available phosphorus were moderate, but the soil total phosphorus and available potassium were abundant. The study results means that the system should focus on nitrogen fertilizer inputting and the controlling of the distribution amount of potassium fertilizer.

Keywords: Intercropping, Alfalfa, Wheat, Soil fertility.

INTRODUCTION

Soil fertility is the basic attribute and essential characteristic of soil, an important index reflecting soil fertility, the ability of soil to supply and coordinate nutrients, water, air and heat for plant growth. It is the comprehensive reaction of soil physical, chemical and biological properties, so it is also the material basis for maintaining agricultural yield stable and improving product quality [1-2]. Many studies have shown that intercropping of gramineous crops with legumes has certain positive effects on soil moisture, soil nutrients, crop agronomic traits, and economic benefits for agricultural yield and quality [3-7]. Intercropping of wheat/alfalfa is a relatively novel intercropping model trying of gramineous/legume crop [8]. This paper combined principal component analysis, systematic cluster analysis and soil nutrient abundance and deficiency diagnosis methods to discuss the soil fertility evaluation of this cropping model experiment, in order to provide references for the next fertilization scheme of this field experiment.

1. MATERIALS AND METHODS

1.1 Test Area

The experimental area is located in Dongdu Village (35° 55’N, 111° 34’E), Xiandi Town, Yaodu District, Linfen City, Shanxi Province. It falls within the warm temperate continental semi-arid monsoon climate zoon with an annual frost-free period of 203 days, the average annual precipitation of 550mm, annual sunshine duration of 2416.5 hours, and average annual temperature ranging from 9 to 13℃. Figure 1 shows Linfen 's temperature and precipitation in 2018.

1.2 Test Materials

The experimental crops were winter wheat (Jinmai 95, 1000-grain weight 40g) and alfalfa (local variety, 1000-grain weight 2.255g). Basic nutrients of the tested soil were shown in table 1 [9]. A total of 25kg compound fertilizer (N-P_2O_5-K_2O: 19-15-6, 270 kg/ hm^2) was applied evenly before wheat sowing every year.

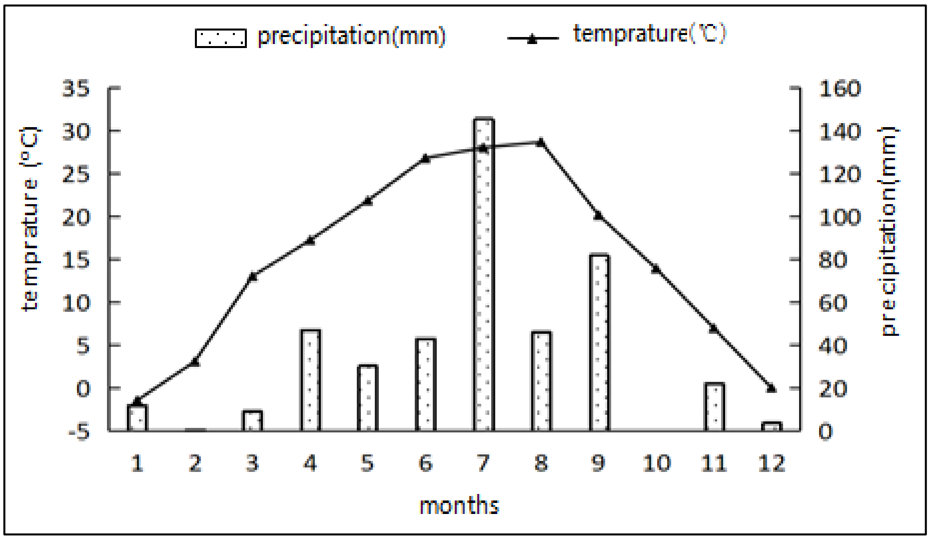

Fig 1: Linfen 's temperature and precipitation in 2018

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)	Available Phosphoric (mg /Kg)	Available Potassium (mg /Kg)
0～20	8.05	21.51	1.18	0.60	20.85	53.82	10.59	235.55

1.3 Experimental Design

The field trial consisted of 3 treatments (wheat monocast XD, alfalfa monocast MD, and wheat/alfalfa intercropping HB) with 3 repetitions respectively. 9 plots ($50m^2$/ plot) were randomly arranged. In April 2014, alfalfa was sown in a north-south direction, with a row spacing of 40cm and a $18kg/hm^2$ seeding rate. Winter wheat was sown in the same direction mechanically and annually on the established perennial alfalfa field in early October, with a 18cm row spacing and seeding rate of $225kg/hm^2$.

1.4 Sampling and Determination Methods

Soil samples of 0-30cm were collected in March, June and October of 2018 respectively, and fresh or air-dried soil samples were prepared according to different test items.

The test items and methods are as follows:

Soil pH: Potentiometric determination with soil-liquid ratio of 1:2.5.

Soil Organic Matter: Potassium dichromate oxidation volume method, heated in oil bath.

Soil Total Nitrogen: Kjeldahl distillation.

Soil Total Phosphorus: NaOH melting - Mo-Sb colorimetric method.

Soil Total Potassium: NaOH melting - Flame spectrophotometry.

Soil Ammonium Nitrogen: Extraction of potassium chloride - Indophenol blue colorimetry (spectrophotometry).

Soil Nitrate Nitrogen: Extraction of calcium chloride - Phenol disulfonic acid colorimetry (spectrophotometry).

Soil Available Phosphorus: Extraction of sodium bicarbonate - Mo-Sb colorimetric method (spectrophotometry).

Soil Available Potassium: Extraction of ammonium acetate - Flame spectrophotometry.

1.5 Data Processing

Excel 2007 was used to calculate data and draw charts, and SPSS21.0 for principal component analysis and cluster analysis.

2. RESULTS

2.1 Evaluation of Soil Fertility

Based on the nutrient classification standards of the second national soil survey (Table 2 and Table 3) [1] and the measurement data of soil samples adopted three time in 2018, the abundance and deficiency of soil elements in wheat/alfalfa intercropping treatments were evaluated (Table 4). The results showed that after four years of wheat/alfalfa intercropping experiment, soils of all treatment showed obvious nitrogen deficiency at different sampling times in the year. All treatments' soil total potassium level were slightly lower, but available potassium were abundant. The contents of total phosphorus were abundant, while available phosphorus were at a medium level.

Table 2: The standard for classifying soil pH levels

Classification	pH
Strongly acidic	<4.5
Acidic	4.5-5.5
Subacidic	5.5-6.5
Neutral	6.5-7.5
Alkalin	>7.5

Table 3: Classification criteria for soil fertility evaluation indexes

Level	OM (g/kg)	TN (g/kg)	TP (g/kg)	TK (g/kg)	AN (mg/kg)	AP (mg/kg)	AK (mg/kg)
1st	>40	>2	>1	>25	>150	>40	>200
2nd	30-40	1.5-2	0.8-1	20-25	120-150	20-40	150-200
3rd	20-30	1-1.5	0.6-0.8	15-20	90-120	10-20	100-150
4th	10-20	0.75-1	0.4-0.6	10-15	60-90	5-10	50-100
5th	6-10	0.5-0.75	0.2-0.4	5-10	30-60	3-5	30-50
6th	<6	<0.5	<0.2	<5	<30	<3	<30

Note: OM means Organic matter, TN、TP、TK means total nitrogen、total phosphorus、 total potassium and AN、AP 、AK means available nitrogen、available phosphorus、available potassium. And the same in below tables.

Table 4: Evaluation results of abundance and deficiency of each element

Treats	Time	pH	OM level	TN level	TP level	TK level	AN level	AP level	AK level
XD	Mar.	neutral	2nd	4th	1st	4th	6th	3rd	2nd
	Jun.	neutral	3rd	5th	1st	4th	6th	3rd	2nd
	Oct.	alkaline	4th	5th	1st	4th	5th	3rd	1st
MD	Mar.	neutral	2nd	5th	1st	4th	6th	3rd	2nd
	Jun.	neutral	3rd	6th	1st	4th	6th	3rd	3rd
	Oct.	alkaline	4th	5th	1st	4th	6th	3rd	3rd
HB	Mar.	neutral	2nd	5th	1st	4th	6th	3rd	2nd
	Jun.	neutral	2nd	5th	1st	4th	6th	3rd	3rd
	Oct.	alkaline	4th	5th	1st	4th	6th	3rd	2nd

2.2 Statistical interpretation of test results

Table 5 shows the descriptive statistics of soil nutrient test results. According to K-S test, the distributions of pH, organic matter, total nitrogen, total phosphorus, total potassium, available nitrogen, available phosphorus and available potassium at different times are normal after the outliers are excluded. It is suitable for principal component analysis.

Table 5: The statistical analysis of soil nutrient test results

Statistical parameter	pH	OM (g/kg)	TN (g/kg)	TP (g/kg)	TK (g/kg)	AN (mg/kg)	AP (mg/kg)	AK (mg/kg)
Mean value	7.67	25.74	0.64	6.69	12.50	20.97	14.68	166.92
standard deviation	0.45	6.34	0.11	1.30	0.99	8.67	2.75	29.98
variable coefficient	0.06	0.25	0.17	0.19	0.08	0.41	0.19	0.18
skewness	0.82	-0.05	-0.47	2.14	0.67	1.45	0.27	-0.12
kurtosis	-1.54	-1.84	-1.25	5.90	0.75	2.74	0.38	-0.18
K-S test	0.010	0.200	0.200	0.012	0.200	0.136	0.200	0.200

2.3 Principal component analysis and systematic cluster analysis for soil fertility

Principal component analysis is a statistical analysis method that divides multiple variables into a few comprehensive indicators, and is widely used in soil fertility evaluation [10-13]. We used principal component analysis for the 8 tested soil fertility indexes including pH, organic matter, total nitrogen, total phosphorus, total potassium, available nitrogen, available phosphorus and available potassium to further evaluate the soil fertility of each treatment comprehensively.

Table 6: Principal component analysis and composite scoring

Treats	Time	Principal component 1		Principal component 2		Principal component 2		Composite score and ranking	
		Score	Ranking	Score	Ranking	Score	Ranking		
XD	Mar.	-0.49	9	0.50	2	0.48	3	-0.14	4
	Jun.	-0.15	4	0.87	1	-0.38	5	1.03	3
	Oct.	0.72	2	0.05	6	1.91	1	4.63	1
MD	Mar.	-0.31	6	-0.55	7	0.95	2	-1.36	7
	Jun.	-0.21	5	-1.22	9	-0.69	7	-4.18	9
	Oct.	0.26	3	-0.65	8	-0.39	6	-0.93	6
HB	Mar.	-0.40	8	0.38	3	0.18	4	-0.37	5
	Jun.	-0.39	7	0.25	5	-0.84	8	-1.68	8
	Oct.	0.97	1	0.36	4	-1.23	9	3.00	2

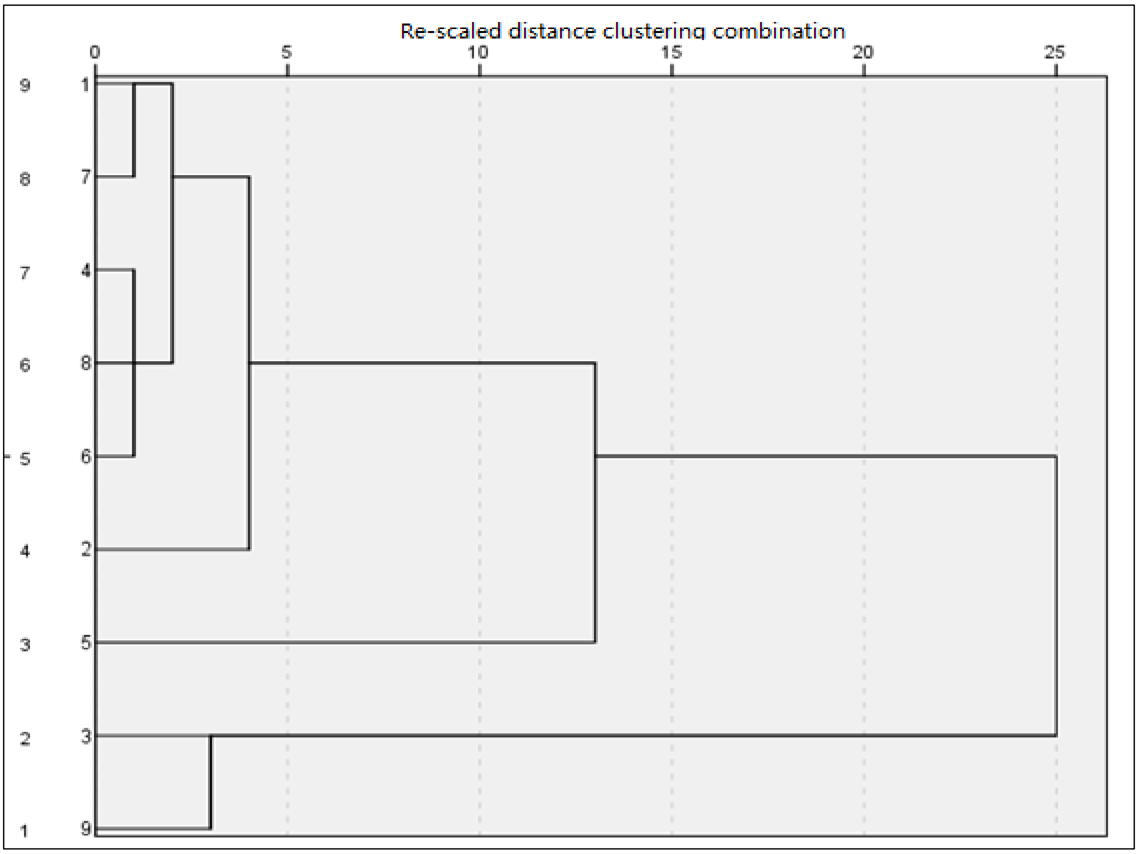

Fig 2: Systematic clustering of comprehensive score

The comprehensive score of the principal component analysis results (as shown in Table 6) was clustered, adopting square Euclidean distance and inter-group joining method. Selecting 10 as clustering distance standard, we have 3 clustered categories from the clustering spectrum diagram (Fig.2). It shows that the soil fertility of XD (October) and HB (October) in the first category were higher. That of the XD (March and June), MD (March and October) and HB (March and June) in second type were medium. The soil fertility of Category 3 MD (June) was poorest.

3. CONCLUSIONS

The results showed that under the experimental conditions of wheat/alfalfa intercropping system for four consecutive years, the soil comprehensive fertility could be maintained at a moderate level, which was mainly reflected in the increase of soil total phosphorus level and the accumulation of organic matter. But the consumption of soil potassium and soil nitrogen was intense, especially for the soil nitrogen, which had reached the point of serious deficiency. In general, the existing experimental conditions and fertilization schemes led to a decrease in the overall soil fertility level. It is necessary to further adjust the fertilization scheme, which should focus on nitrogen fertilizer input increasing, appropriately control the amount of potassium, and reduce using amount of phosphate.

4. DISCUSSION

The soil fertility evaluation results of the three treatments shows that although alfalfa has nitrogen fixation ability, it consume soil nitrogen severely in this experiment, especially in the first half part of the year, which may be closely related to the growth rhythms of alfalfa [14]. It should also be the main reason for the large nitrogen consumption of wheat/alfalfa intercropping. On the other hand, wheat competition may also be a factor hindering the nitrogen fixation function of alfalfa, which needs to be further verified and discussed. Although the fertility level of monosowed alfalfa is low, that of wheat/ alfalfa intercropping is medium. This difference verified the viewpoint mentioned by Lu Yixiao *et al.*, [6] that it is possible to achieve soil fertilization by mixed sowing of grass/beans. After all, legumes can fix atmospheric nitrogen and supply neighboring plants for growth through direct or indirect nitrogen transferring. Moreover, the litter of leguminous plants has high nutrient quality and decomposed fast, which can speed up nutrient cycling process. Soil nutrient balance is one of the important conditions for the normal growth and development of plants, which often needs to be adjusted by fertilization to supplement the deficiency of soil nitrogen, phosphorus and potassium nutrients and play the role of increasing production and quality [10-11]. It is also necessary to make the next fertilization plan to adjust the nutrient balance and deficit of the wheat/alfalfa interacting system.

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