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Characteristics of phosphorus chemistry and its geographical distribution in the Haihe River valley, North China

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Abstract—The study on the phosphorus element chemistry in plants, geographical distributions, outputs and inputs of phosphorus from the soils by 61 plants in the Haihe River valley, North China, are presented in this paper.

Keywords: phosphorus contents in plants; geographical distribution; Haihe River valley.

1 Introduction

Research on element chemistry and biogeological cycle of elements in ecosystems (Chen, 1985; Wang, 1988; Upadhyay, 1989; Zhang, 1990), is an important aspect of ecosystem study. Element levels and their geographical distributions in different components of an ecosystem, can not only be used as indicators of habitat condition, but also provide scientific guidance for the application of fertilizers in practice. The adsorption (Chapman, 1989), Dynamic (Dichinson, 1984; Chapman, 1989), efficiency (Zhao, 1990), cycling (Zhang, 1990; Chen, 1985), immobilization and release (Upadhyay, 1989) of phosphorus in both soil and plant have been studied extensively in resent years. From this it is clear that an examination of phosphorus contents in different species and different places, especially in an intensive farming area where the cycle of phosphorus in the agricultural ecosystem has been artificially altered could be of considerable interest.

The Haihe River valley is an important agriculture region in North China. But problems of the constant danger of infertilization, saline-alkalization and desertization are serious in that area as a result of the intensive farming, the losses of phosphorus in the soil being particularly obvious (Zhao, 1990). The purpose of the work described in this paper is to see the characteristics of phosphorus content in plants and the distributions of phosphorus in both plants and soils in the area, the input and output of phosphorus by plants, and the patterns of phosphorus cycle in the agriculture ecosystem. Such a kind of research could provide an ecological base for applying fertilizers and guiding agriculture management in the region.

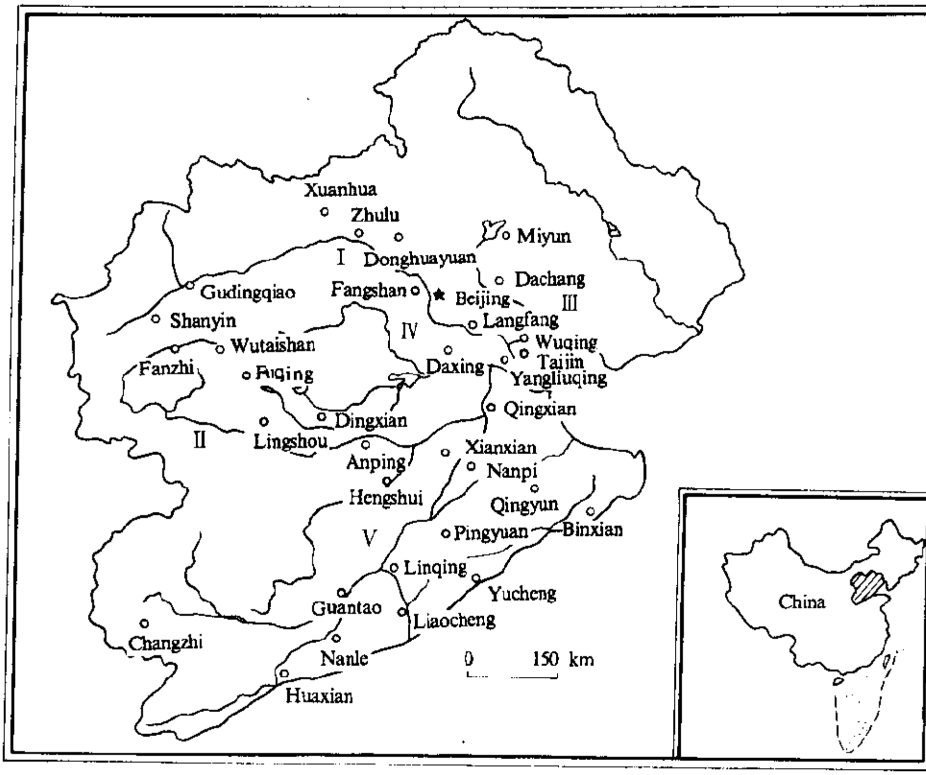

Fig. 1 The sketch of the study area

I. Yongding River II Haotuo River III Daqing River IV. Chaobai River V. Zhangwei River

2 Study area

The study was conducted in the Haihe River valley, North China, 35°00″ to 41°30′N and 112°00′ to 118°30′E, which covers an area of 260000 km^2 and includes Hebei, Henan, Shandong, Shanxi provinces (part), Inner Mogolia Autonomous Region(part), Beijing, Tianjin cities (part). There are six main rivers, namely Jiyun, Chaobai, Yongding, Daqing, Haotuo and Zhangwei(Fig. 1). From east to west, there are the different geographical land forms, they are the Haihe Accumulation Plain formed in the Quaternary Period, the Taihang Mountain, the Yanshan Mountain, the Xinxian Basin, the Datong Basin, and the Yangyuan - Yunxian Basin in the west part of Shanxi Graven, along an attitudinal gradient from 1 m to 3058 m. The soil types are mainly the cinnamon soil, the moisture soil, the sandy soil, the saline soil, the brown earth soil, and so on.

The Haihe River valley is situated in a temperate climate region, with mean year temperature of 14℃, annual rainfall 300mm to 950mm, 80% of which occurring in July and August. The coldest month is January with mean temperature - 1. 6℃ and the warmest month is July which has the mean temperature 23. 5℃. The sum of temperatures which are >10℃ is 1622℃

to 4600℃, and the non frost days are from 70 to 220 days. In such climate and soil conditions develop the temperate mixed broadleaf decidous and needle leaf evergreen forests, with *Quercus spp.*, *Populus davidiana* Dode, *Betula platypkylla* Suk. *Pinus tabulaeformis* Carr., *Larix principis-rupprechtii* Mayr. being the dominant species. In some saline-alkali soil areas near the sea shore, saline grassland can be found. Most of the area, however, has now been converted into agricultural land, with main crops being *Triticum aestivum* L., *Zea mays* L., *Sorghum vulgare* Pers., *Clycine max* (L.) Merr., *Gossypium hirsutum* L., together with some fruit trees.

3 Methods

The works of vegetation surveying and sampling were done by driving cars along the main vegetation areas. Samples of plants and soils were collected on the following dates: September to October, 1988; July to August and September to October, 1989. 426 samples of 61 plant species and 21 soil samples were collected. Four parts, roots, stems, leaves, and fruits of the extensively distributing artificial vegetation in the Haihe River valley such as *Zea mays* L., *Clycine max*(L.) Merr., *Sorghum vulgare* Pers., and *Panicum miliaceum* L. and so on were collected respectively, while for the rest species, just the above-ground parts, and leaves and young branches were collected. The different parts of plant samples were weighed on the spot and their biomasses were calculated after air-drying. For analysis, the samples were cleaned, air-dried, ground and acid-digested with redistilled HCl-HNO_3 and $HClO_4$. The total phosphorus was analyzed by using 721 Calorimetric Analysis Spectrometer (Nanjing Agriculture University, 1980). 0.5g sample was used for the analysis and a duplicate sample was measured in order to get a precise result.

Table 1 Total phosphorus content ($mg.g^{-1}$, dry weight) of 61 species in the Haihe River valley*

Species	Variable range	Mean
Acer mono Marxim	0.84—1.80	1.12
Betula platyphylla Suk.	0.35—0.65	0.55
Ailanthus altissima (*Mill.*) Swinggle	0.90—1.60	1.25
Populus davidiana Dode	0.98—1.68	1.32
P. simonii Carr.	0.86—1.77	1.21
P. cathyana Rehd.	1.04—1.60	1.35
P. canadensis Moench	0.74—1.89	1.36
Robinia pseaudoacacia L.	1.10—2.11	1.68
Sophora japonica L.	0.89—1.95	1.75
Salix matsudana Koidz	0.58—2.27	1.56
S. babylonica L.	1.03—2.97	1.96
Paulownia tomentosa Setud	0.89—1.35	1.12
Plataunus orientalls L.	0.83—1.22	0.89
Fraxinus chinese Roxb.	1.06—1.45	1.37
Pinus tabulaefomis Carr.	0.74—1.15	0.98

Table 1(**continued**)

Species	Variable range	Mean
Larix principis-rupprechtii Mayr.	0.69—1.14	0.98
Spiraea trilobata L.	0.71—1.20	1.15
Carex rigescens (Franch.) Krecz.	0.66—1.67	1.19
Themeda triandra Forsk	—	0.46
C. heterostachya Bunge	—	1.39
C. sp.	—	1.15
Phlomis umbrosa Turcz	—	2.04
Thalictrum baicalense Turcz	—	1.78
Roegneria kamoji Ohwi	—	1.23
Sanguisorba officinalis L.	—	1.23
Gentiana macrophylla Pall.	—	1.45
Lysimachia foenum-graecum Hance	—	1.36
Oxytropis corulea (Pall.)DC.	—	1.77
Zizyphus jujuba var. chineris (Bunge) Rehd.	—	0.67
Malus asiaica Nakai	0.66—1.50	1.16
Pyras pyriolis (Burm.) Nakai	1.08—1.71	1.44
Selaginella sp. (a)	—	2.46
S. Sp. (b)	—	1.41
Musci sp.	—	1.37
Phragmites comunis Trin	0.43—1.21	0.75
Lemna minor L.	—	0.43
L. sp.	—	0.51
Tamarix chinese Lour.	0.10—1.03	0.54
Artemisia scoparia Wald.	1.27—2.72	2.12
A. Sacrorum Ledeb	0.66—1.72	1.41
A. sp.	1.17—1.36	1.30
Suaeda heteroptera Kitag.	0.86—1.68	2.00
Aeluropus littorlis Debx	1.52—2.68	1.81
Zea mays L.	0.45—3.93	1.56
Sorghum vulgare Pers.	0.26—3.26	1.21
Panicum miliaceu L.	0.99—3.42	1.47
Oryza sativa L.	0.81—2.30	1.47
Triticum aestivum L.	0.34—1.91	0.89
Avena nuda L.	0.86—0.92	0.89
Ipomoea batatas (L.) Lam	0.65—2.66	1.74
Clycine max (L.) Merr	0.76—3.21	1.75
Arachis hypogaea L.	0.68—4.04	2.02

Table 1 (continued)

Species	Variable range	Mean
Gossypium hirsutum L.	0.57—3.25	1.47
Helianthum annuus L.	0.63—2.36	0.90
Seasamum indicum L.	0.54—1.10	0.98
Canabis sativa L.	0.69—1.80	1.16
Solanum tuberosum L.	0.77—2.75	1.19
Brassica junicea (L.) Czern.	0.32—1.20	0.73
B. pekinensis Rupr.	1.21—2.98	2.10
Prunus armeniaca L.	0.69—1.98	1.44
Malus pumila Mill.	0.95—1.07	0.91

* The parts of species used for chemical analysis include leaves and young branches if the samples are from trees, and the above-ground parts from shrubs and natural grasses, the roots, stems, leaves and roots from crops and vegetables, and the whole bodies from *Selaginella spp.*, *Musci spp.* and *Lemna spp.*

4 Results

4.1 The phosphorus chemistry of plants

Table 1 shows the results of the measured P contents of 61 plant species of the Haihe River valley, and Table 2—4 are gained by data proceeding from Table 1. From these tables, we can see the chemical characteristics of phosphorus contents of the main species in the area as follows:

The average P content of the 61 species in the Haihe River valley is 1.29 ± 0.43 mg·g^{-1}, among which *Artemisia scoparia* Wald. et Kitaib. has the highest concentration, 2.21mg·g^{-1} and *Lemna minor* L. the lowest, 0.43mg·g^{-1}. The result is generally similar to that of the 122 species in the Xilin River valley in Inner Mongolia Region (Chen, 1985), which is 1.51 ± 0.65 mg. g^{-1}, with the highest 3.86 mg. g^{-1} and the lowest 0.47 mg. g^{-1}. The two results indicate that P is the middle-content element and relative stable in plants.

Table 2 Total phosphorus (mg. g^{-1}, dry weight) of the different vegetation types in the Haihe River valley

Vegetation types	Variable	Mean
Deciduous broadleaf trees	0.55—1.96	1.32
Needle leaf trees	—	0.98
Shrubs and sub-shrubs	1.15—1.41	1.29
Natural grasses	0.42—2.12	1.37
Water plants	0.43—0.75	0.56
Halophilous plants	0.54—2.12	1.62
Crops	0.89—2.02	1.36
Vegetables	0.73—2.10	1.34
Fruit trees	0.67—1.44	1.22

Table 3 Total phosphorus content (mg. g^{-1}, dry weight) of the different parts of the species in the Haihe River valley, and analysis of variance of the sample data

Species/Parts	Amount of samples	Variable range	Mean	*S. D.*	*C. V.* (%)
Zea mays L.					
Root	26	0.20—1.84	0.72	0.34	47.2
Stem	30	0.25—3.01	1.03	0.67	65.0
Leaf	34	0.45—3.81	1.83	0.70	38.3
Fruit	19	0.32—3.93	2.66	0.88	30.1
Sorghum vulgare Pers.					
Root	6	0.24—1.07	0.60	0.29	48.3
Stem	10	0.12—2.13	0.95	0.68	71.6
Leaf	10	0.26—3.26	1.65	0.95	57.6
Fruit	5	0.19—3.27	1.65	1.25	73.6
Panicum miliaceum L.					
Root	8	0.14—1.06	0.69	0.34	49.3
Stem and leaf	8	0.23—2.74	1.17	0.75	64.1
Fruit	7	1.99—3.42	2.55	0.51	20.0
Oryza sativa L.					
Stem and leaf	3	1.80—3.24	2.30	0.81	35.2
Ipomoea batatas (L). Lam.					
Root	3	1.33—2.70	1.99	0.69	34.7
Stem and leaf	3	1.41—1.90	1.50	0.36	24.0
Clycine max (L). Merr.					
Root	13	0.48—1.90	1.16	0.47	40.5
Stem	15	0.72—3.65	1.45	0.78	53.8
Leaf	14	0.65—2.69	1.68	0.67	37.2
Fruit	4	1.00—3.68	2.66	1.17	44.0
Gossypium hirsutum L.					
Root	10	0.57—1.78	1.01	0.41	40.6
Stem	9	0.30—1.67	0.95	0.45	47.4
Leaf	15	0.60—3.28	1.73	0.80	46.2
Fruit	8	1.60—3.25	2.17	0.57	26.3
Helianthus annuus L.					
Leaf	3	0.77—2.36	1.45	0.82	56.6
Solanum tuberosum L.					
Leaf	3	1.49—2.75	2.14	0.65	30.4
Populus canadensis Moench.					
Leaf	5	0.74—1.89	1.36	0.46	33.8
P. simonii Carr.					
Leaf	3	1.02—1.43	1.21	0.21	17.4
Robinia pseaudoacacia L.					
Leaf	3	1.10—2.11	1.68	0.52	31.0
Salix matsudana Koidz.					
Leaf	5	0.58—2.27	1.56	0.70	44.9
Pinus tabulaeformis Carr.					
Leaf	3	0.71—1.15	0.98	0.22	22.4
Tamarix chinensis Lour.					
Leaf	3	0.10—1.03	0.54	0.47	87.0
Phragmites communis Trin.					
Above-ground parts	4	0.43—1.21	0.75	0.38	50.7
Suaeda heteropera Kitag.					
Above-ground parts	3	1.27—2.72	2.12	0.76	35.8
Carexs rigescen (French.) Krecz.					
Above-ground parts	3	0.66—1.67	1.19	0.50	42.0

The 61 species are divided into deciduous broadleaf trees, needle leaf trees, shrubs and mid-shrubs, natural grasses, water plants, halophilous plants, crops, vegetables and fruits trees, according to their habitats and distributions and the traditional customs of agriculture. The P contents vary according to the diffferent kinds of vegetations, among which the halophilous plants have the highest P contents, nearly 2.0 mg. g^{-1}, the rest have relative lower P contents, with an order of , halophilous plants>natural plants> crops > vegetables > deciduous broadleaf trees > shrubs and mid-shrubs > fruit trees > needle leaf trees> water plants (Table 2). Among the crops, *Arachis hypogaea* L. > *Ipomoea batatas* (L.) Lam. > *Clycine max*(L.) Merr. > *Oryza sativa* L. >*Zea mays* L. > *Panicum miliaceum* L. >*Sorghum vulgare* Pers. >*Cannicum sativa* L. >*Sesamum indicum* L. >*Triticum aestivum* L. >*Helianthus annuus* L. >*Avena nuda* L.; the deciduous broadleaf trees: *Salix babylonica* L. >*Sorphora japonica* L. >*Robinia pseudoacacia* L. >*Salix matsudansa* Koidz> *Fraxinus chinensis* Roxb. > *Populus canadensis* Moench> P. cathayana Rehd. >P. davidiana Dode>Ailanthus altissima (Mill.) Swingle> *Populus simonii* Carr. >*Acer mono* Maxim>*Paulownia tomentosa* Steud. >*Platanus orientalls* L.; the natural grasses, *Phlomis umbrosa* Turcz. >*Thalictrum bailense* Turcz. > *Oxytropis corulea*(Pall.) DC. >*Selaginella* sp. (B)>*Lysimachia foenum-graecum* Hance> *Sanguisorba offficinalis* L. > *Carex rigeseans* (Franch)Krecz. >*Carex* sp. >*Themeda triandra* Forsk. var. *japonica* (Willd.) Makino(Table 1).

Table 4 Total phosphorus content(mg. g^{-1}, dry weight) in the roots of *Zea mays* L. in the different subsidiary areas of the Haihe River valley

Subsidiary areas	Elevation, m	Soil types	*n*	Variable range	Mean	*S.D.*	*C.V.*(%)
Haotuo	134—3058	Ⅰ, Ⅱ	5	0.22—1.55	0.85	0.49	57.6
Yongding	24—1291	Ⅰ, Ⅱ, Ⅲ	2	0.73—0.74	0.74	0.01	1.4
Zhangwei	3—51	Ⅲ, Ⅳ	10	0.45—0.78	0.64	0.12	18.7
Daqing	1—7	Ⅲ, Ⅳ	4	0.33—0.78	0.54	0.20	37.0
Chaobai	1—16	Ⅱ, Ⅳ	4	0.42—0.82	0.62	0.20	32.3

Ⅰ. Cinnamon soil Ⅱ. Brown soil Ⅲ. Moisture soil Ⅳ. Saline-alkali soil

The different P contents are also found in the different parts of the following species (Table 3), *Zea mays* L., *Panicum miliaceum* L., *Sorghum vulgare* Pers., *Clycine max*(L.,)Merr., and *Gossypium hirsutum* L., with a sequence (the mean content of the five species) of fruit (2.34mg. g^{-1})>leaf(1.61mg. g^{-1})>stem(1.11 mg. g^{-1})>root(0.84mg. g^{-1}). On the other hand, however, *Ipomoea batatas*(L.) Lam. has the higher P content in the root, and *Helianthus annuus* L. and *Sesamun indicum* L. have the relative higher P contents in leaves.

4.2 The geographical distributions of plant phosphorus

The characteristics of plant element chemistry are determined partly by their physiological demands and partly by the surrounding geographical environments, i.e., different habitats bear the different element contents in the soils, while the plants, as the indicators of environmental habitats can reflect the phenomenon. The phosphorus absorbed by plants is mainly from the phosphorus pool of soil from either rock - eroding or manmade fertilizer. So the P contents vary in the different areas even in the same species because of the different habitats and the degrees of human activities. Take *Zea mays* L. , the P concentrations in the roots vary in the different subsidiary area of the Haihe River valley (Table 4).

In the five subsidiary areas of the Haihe River valley, the Haotuo River valley has the highest P content in the root of *Zea mays* L. , which is 0. 85 mg. g^{-1} the second is Yongding River valley, 0. 74 mg. g^{-1} then are the Zhangwei River valley, Chaobai River valley and Diqing River valley, with P contents being 0. 64 mg. g^{-1}, 0. 62 mg. g^{-1} and 0. 54 mg. g^{-1} respectively. The latter three areas locate in the east part of the Haihe River valley, where there is the intensive agricultural activities.

4. 3 The input and output of phosphorus

For the agricultural soil - plant ecosystem, the above ground parts, i. e. , leaves, stems and fruits, are harvested, the P contents in these parts are then moved from the soil, by which we name the outputs of phosphorus from the soil. On the other hand, the P contents in the roots which are remained in the soil and become the soil content after decay, are called the inputs of phosphorus to the soil. The P inputs and outputs by the main crops and natural grasses in the Haihe River valley are showed in Table 5. *Panicum miliaceum* L. has the highest output among the crops, which is 44. 853 kg P $ha^{-1}. a^{-1}$, while *Helianthus annuus* L. , the lowest, has only 0. 261kg P $ha^{-1}. a^{-1}$. The natural grasses, however, have the relative lower P output, for example, the P outputs are 0. 595 kg P ha^{-1}. a ^{1}and 0. 460 kg $ha^{-1}. a^{-1}$ in *Carex rigescens* (Franch.) Krecz. and *Themeda triandra* Forsk. var *japonica* (Wild.) Makino, respectively. The series of the ten species which have the higher P outputs is *Panicum miliaceum* L. > *Zea mays* L. > *Sorghum vulgare* Pers. > *Arachis hypogaea* L. > *Impomoea batatas* (L.) Lam. > *Sesamum indicum* L. > *Solanum tuberosum* L. > *Clycine max* (L.) Merr. > *Triticum aestirum* L. > *Oryza sativa* L. roots of *Zea mays* L.

Among the crops, *Ipomoea batatas* (L.) Lam. has the highest P input, which contributes 12. 557 kg P $ha^{-1}. a^{-1}$ to the soil, while *Brassica juncea* (L.) Czern. et Coss. has the lowest input, only 0. 141 kg P $ha^{-1}. a^{-1}$.

5 Discussion

5. 1 Insufficient of available phosphorus in the soils

The content of total P in the plants which are insufficient in phosphorus nutrient is about 1. 0 mg. g^{-1} of dry biomass or less, while on the conditions of sufficient available P provided in the soils, the crops and herbal grasses can contain total P more than 3. 0 to 4. 0 mg. g^{-1} (Zhang, 1987). The average P content in the crops of the Haihe River valley is 1. 28 mg. g^{-1}, even the highest, 1. 59 mg. g^{-1} (*Oryza sativa* L.), being lower than the level of 3. 0 to 4. 0 mg. g^{-1}, which indicated that there is probably insufficient of efficient P in the soils of that area, because the soil available P is the main resources for crops.

The total amount of P absorbed by some crops per year is even higher than that of the available P storage in the soil reservoir. For example, the amount of P absorbed by *Zea mays* L. is 34.006 kg P $ha^{-1}.a^{-1}$, and 49.145 kg P $ha^{-1}.a^{-1}$ by *Panium miliaceum* L., 23.242kg P $ha^{-1}.a^{-1}$ by *Ipomoea batatas*(L.) Lam, 28.396kg P $ha^{-1}.a^{-1}$ by *Gossypium hirsutum* L. etc, (Table 5), while the available P storage in the soil pool of the Haihe valley is about 18.8 to 56.8 kg P ha^{-1}, which could not meet even one year's phosphorus demand for some crops (Zhao, 1990). It is obvious that the soils in the area are insufficient of P nutrient.

Table 5 The phosphorus output and input(kg $ha^{-1}.a^{-1}$) by the main crops and natural grasses in the Haihe River valley, with the total amount of phosphorus absorbed by the plants (output+input) and the net loss of phosphorus(output - input) due to harvesting the above ground parts, and the ratios of output:input

Species	Output	Input	Output+Input	Output−Input	Output:Input
Zea mays L.	32.661	1.405	34.066	31.256	23:1
Sorghum vulgare Pers	13.442	1.637	15.079	11.805	8:1
Panicum miliaceum L.	44.853	4.292	49.145	40.561	10:1
Oryza sativa L.	3.850	0.730	4.580	3.120	5:1
Triticum aestivum L.	5.413	0.730	6.143	4.583	7:1
Avena nuda L.	0.489	0.258	0.747	0.231	2:1
Ipomoea batatas(L.) Lam	10.685	12.557	23.242	−1.872	0.9:1
Clicine max(L.) Merr.	6.584	0.353	6.937	6.231	19:1
Arachis hypogaea L.	10.751	2.451	13.202	8.300	4:1
Gossypium hirsutum L.	26.591	1.805	28.396	24.286	15:1
Helianthus annuus L	0.261	0.205	0.466	0.056	1:1
Sesamum indicum L.	9.346	1.577	10.923	7.769	6:1
Solanum tuberosum L.	7.580	0.393	7.973	7.187	19:1
Brassica juncea L.	1.525	0.141	1.666	1.384	11:1
Carex rigescens Krecz.	0.595	0.289	0.893	0.297	2:1
Themeda triandra Forsk.	0.460	0.234	0.694	0.228	2:1

Among the five subsidiary areas of the Haihe River valley, the Zhangwei River valley, the Daqing River valley and the Chaobai River valley have even the lowest contents of soil available P from the fact that the P contents in the roots of *Zea mays* L. of the three areas are lower. The reasons for that phenomena seem to be that: (1) the main types of soil of the three areas belong to saline - alkali soils, which affect the absorption of P from the soils, because the high pH in the soil solution, according to Zhang and Liu(Zhang, 1987), determines the speed of adsorption of P. The speed of adsorption of P by plants is 10 times higher when the soil pH is 4 than that of pH 8.7. (2) the three areas are situated in the Northern China plain where the agricultural activities are intensive, through which a great amount of available P in the soil are taken away by harvesting crops.

5.2 Losses of soil available phosphorus due to harvest

5.2.1 The harvest parts contain more phosphorus

In the ripen straws of the crops, the content of P is lower, which is about 1.0 to 1.5 mg. g^{-1}, while in the seeds and grains of crops, the concentration may rise to about 4.0 to 5.0 mg. g^{-1}(Zhang, 1987). The phenomenon indicates that during the ripen process, there is a plenty of P being transported from the leaves and stems to the seeds and grains. The inorganic P exists as the storage form in the plant body; while the organic P, as the necessary component of anabolism, exists in the active parts of the body and is unstable. That the seeds and grains contain high level of P could be explained by storing a great amount of inorganic P. Besides the seeds and grains, the stems and leaves also contain relative higher level of P than the roots. Our result showed that, the three parts of fruits (2.34mg. g^{-1}), stems (1.11 mg. g^{-1}) and leaves (1.61 mg. g^{-1}) of *Zea mays* L., *Panicum miliaceum* L., *Sorghum vulgare* Pers., *Clycine max* (L.) Merr. and *Gossypium hirsutum* L., contain phosphorus 6 times higher than that of roots (0.84 mg. g^{-1}), which means a lot of phosphorus will be lost due to harvesting the above ground parts, if the harvest parts are not returned to the soil.

5.2.2 More output than input

The output of P per hectare by plants, besides the small amount of P in the sowing seeds, is mainly from the available P in the soils. The higher the ratio of output:input, the more the available P is lost, while the less is returned. Except *Ipomoea batatas* (L.) Lam. and *Helianthus annuus* L., the agricultural plants of the Haihe River valley output more phosphorus than input, the ratios of output:input being from 2:1 to 23:1. The ratios of output :input of *Zea mays* L., *Clycine max* (L.) Merr., *Solanum tuberosum* L., *Gossypium hirsutum* L. are 23:1, 19:1, 19:1 and 15:1, respectively. On the other hand, the natural grasses, like *Carex rigescens* (Franch.) Krecz. and *Themeda triandra* Forsk. var. *japonica* (Willd.) Makino have the lower ratios of output:input, which are only 2:1, and the above-ground parts can return to the soils when become decomposed. Such belongs to the normal nutrient cycle type. Although the output:input of *Ipomoea batatas* (L.) Lam is only 0.9:1, the roots used for calculating the biomass include the edible parts, the tube roots, which are harvested every year, so the input part of phosphorus is still small.

5.2.3 Speed of the loss of available phosphorus

In order to forecast the speed of the loss of the available phosphorus in the agricultural ecosystem of the Haihe River valley, we should firstly investigate the storage of P in the soil. 21 soil samples from the Haihe River valley were analyzed, with an average concentration of total P 420 $\mu g. g^{-1}$. Given such a result, the P storage in the soil pool is calculated as 470-1420kg P ha^{-1} (supporting the farming soil layer is 30 cm and the soils of a hector weighs 2250000kg), which is near to that of 428 kg P ha^{-1} in the Beijing, Tianjin and Bohai areas in the same river valley. The storage, if near to the real amount, indicates that when planting *Zea mays* L. (having the P output 31.256 kg P $ha^{-1}. a^{-1}$, input 1.405 kg P $ha^{-1}. a^{-1}$, with a net P loss of 31.601 kg P $ha^{-1}. a^{-1}$, Table 5), the time when the soil lost their total P by harvest is about 20 to 40 years. The rest can be deduced similarly that, when planting *Clycine max* (L.) Merr., the time will be

80 to 2302 years; *Solanum tuberosum* L., 70 to 800 years; *Gossypium hirsutum* L., 20 to 60 years; *Themeda triandra* Forst. var. japonica (Willd.) Makino, 2070 to 6280 years, and so on. In fact, since a lot of P in the soil is not available for the plants, the soil will be short of P earlier than expected.

5.3 Approaches for solving the problem

There are two methods to solve the insufficient phosphorus problem in the Haihe River valley. Firstly, supply the phosphorus fertilizers to the soil, which have the conspicuous results in increasing the grain output, because some active phosphate in the fertilizer easily become inactive, the amount of phosphorus fertilizers supplied should be more than that absorbed by plants, normally 10%-50% more (Zhang, 1987). For this reason, the amount of phosphorus fertilizers applied when planting *Zea mays* L. should at least be 38 to 51 P $ha^{-1}.a^{-1}$, *Panicum miliaceum* L., 54 to 74 kg P $ha^{-1}.a^{-1}$; *Gossypium hirsutum* L., 31 to 43 kg P $ha^{-1}.a^{-1}$; *Ipomoea batatas* (L.) Lam., 28 to 35 kg P $ha^{-1}.a^{-1}$, *Sorghum vulgare* Pers., 17 to 23 kg P $ha^{-1}.a^{-1}$; *Triticum aestivum* L., 7 to 9 kg P $ha^{-1}.a^{-1}$; *Clycine max* (L.) Merr., 8 to 10 kg P $ha^{-1}.a^{-1}$; *Arachis hypoguea* L., 14 to 20 kg P $ha^{-1}.a^{-1}$, and so on. By doing so, we can on the one hand satisfy the need of P by crops, and on the other hand, not waste the fertilizer. Secondly, return the straws to the soils. Through which, the soil can not only get the minerals such as N, P, K after the straws decay, but also increase the content of organic materials as well as improve the soil structure. Unfortunately, this method has been being neglected, especially in the intensive agricultural area in China like the Haihe River valley, where the straws are cleared from the fields and burned as firewood. Although adding fertilizers can tentatively solve the minimal shortage of the soil, it is expensive and wasteful, and easily cause soil pollution. So, here we strongly recommend the second method which can bring the normal nutrient cycle to the agricultural ecosystem.

6 Conclusions

Among the 61 species, *Artemisia scoparia* Wild. et Kitaib. has the highest phosphorus content and *Lemna minor* L. the lowest, with total phosphorus contents of 2.12 mg. $g^{-1}$and 0.43 mg. g^{-1} resectively. The average phosphorus content of *Zea mays* L., *Sorghum vulgare* pers., *Panicum miliaceum* L., *Oryza sativa* L., *Tritium aesivum* L. and *Avena nuda* L. is$<$2.00 mg. g^{-1}, which is less than that of the normally growing crops. The phosphorus content of different vegetation types are in the order: halophilous plants$>$natural grasses$>$crops$>$vegetables$>$broadleaf trees$>$shrubs and mid-shrubs$>$needle leaf trees$>$water plants.

The grain has the highest phosphorus content among the different parts of crops, then the leaf and stem, while the root the lowest, with the contents being 2.34, 1.61, 1.11 and 0.84 mg. g^{-1}respectively, which means a lot of available soil phosphorus is output by harvesting the above ground parts of crops.

The phosphorus contents in the roots of *Zea mays* L. from different subsidiary river valleys in the Haihe River valley are different, the order: Haotuo River$>$Yongding River$>$Zhangwei River$>$Chaobai River$>$Daqing River.

The output of phosphorus by the crops from the soil is 22 more than the input. If straws are not returned to the soils, then crops of *Panicum miliaceum* L., *Zea mays* L., *Gosypium hirsutum*

L. and so on will cause the soil to lose phosphorus at the speeds of 44 kg P $ha^{-1}.a^{-1}$, 32 kg P $ha^{-1}.a^{-1}$, and 26 kg P $ha^{-1}.a^{-1}$. To balance the outputs and inputs it is necessary firstly to add phosphorus fertilizer to the soil, and secondly to return all plant remains to the field.

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