

## Characteristics and nutrient diagnosis of vegetable soils in Tianjin

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**Summary** This paper reports the diagnosis studies of soil nutrient status and deficiency of 12 nutrients elements by using the systematic approach of soil nutrient status. The characteristics of vegetable soils, the nutrient balance of different vegetable soils and the limiting factors and their extent to reducing yield in developing and developed vegetable soils were studied. And the balance fertilization for further yield-increasing and quality improving was recommended.

**Key words** vegetable soil, nutrient diagnosis, balance fertilization

### Introduction

Vegetable production is an important component of agriculture in suburb areas. Because of intensive cropping, application of large amounts of organic manure, and good irrigation, the maturation process in vegetable soil is accelerated and the features of vegetable soils are quite different from those of farmland soils. It is important to study the vegetable soil nutrients and limiting factors of fertilizing the soil, thereby recommending the balance fertilization for increasing yield, and economic benefit return and improvement of in vegetable production.

Tianjin has a long history of vegetable planting. There are about 17,300 ha land for planting vegetable. The production meets the demand of the five million citizens in Tianjin city besides some for export. The 100-years old developed vegetable fields amount to one fifth of the total vegetable planting area, and the recently developing fields account to two fifths. For a long time the fertilizer applied in vegetable soils mainly was nitrogen, and little potash was supplied. The trouble was that the imbalance of nutrient limited further increasing yield and improving quality. By using the systematic approach of soil nutrient status (Hunter, 1980) introduced to China by Sam Portch (1988) and through studies on the nutrient status and deficiency of 12 nutrients elements in 8 sites of vegetable soils with different planting ages, some co-existing limiting nutrients in vegetable soils were found and the scientific bases for obtaining maximum yield and high quality and maximum benefit return in vegetable production were provided.

### Materials and methods

#### *Location of sampling and sample treatment*

Vegetable soils with different planting ages were selected from 8 sites (Table 1). 70 kg soil samples in 0—20cm level were collected from every site. After airing the soils were refined through 2mm mesh. 1kg of the soil samples was used for routine analysis and absorption test, and the rest was used for survey in greenhouse.

**Table 1.** Main features of sampling sites

Soil sample No.	Location	Soil type	Planting year	Texture	Cropping system
TO-1	Shiliujie	Chao soil	100	Light loam	Chinese cabbage, Cucumber, Soy bean
TO-2	Lilou	Chao soil	30	Heavy loam	Spinach, Tomato, Cucumber
TO-3	Xijie	Chao soil	20	Medium loam	Tomato, Califlower, Celery
TO-4	Zhaizhuang	Salinized Chao soil	10	Light clay	Cabbage, Cucumber, Chinese cabbage
TN-1	Xiao Zhangzhuang	Moist Chao soil	5	Medium loam	Water melon
TN-2	Xi Shuangtang	Moist Chao soil	2	Heavy loam	Water melon
TN-3	Shui Gaozhuang	Chao soil	1	Light loam	Tomato, Cabbage, Cucumber
TN-4	Lilou	Salinized Chao soil	1	Light loam	Alley intercropping of grape and vegetable

TO: Tianjin developed vegetable soil; TN: Tianjin developing vegetable soil

#### *Routine analysis and absorption test of soil samples*

The soil physical and chemical features were analysed by methods recommended by ASI (Agriculture Service International). This work was conducted with help of the laboratory of Beijing Office, PPI/PPIC. The results were listed in Table 2.

**Table 2.** Results of routine analysis of eight soil samples

Soil Sample No.	Acid Base	pH	OM (%)	CEC	Ca	Mg	K	Na	Ca/Mg	Mg/K	N	P	S	B	Cu	Fe	Mn	Zn	Electric conductivity (ms/cm)	
					(meq/100ml)					(μg/ml)										
TO-1	0.0	—	8.09	0.56	15.7	10.0	3.89	0.33	1.44	2.57	11.8	18.1	225	112.5	1.83	7.2	36.7	4.6	14.7	0.591
TO-2	0.0	0.0	8.17	0.61	22.3	15.0	5.07	0.21	1.98	2.96	24.1	16.8	107	102.8	3.02	6.2	14.4	2.7	13.7	0.418
TO-3	0.0	0.0	7.95	0.43	19.1	12.3	4.85	0.30	1.63	2.54	16.2	19.7	145.6	140.3	2.71	5.7	23.7	6.0	16.6	0.784
TO-4	0.0	0.0	8.31	0.38	22.1	13.5	6.09	0.33	2.18	2.20	18.5	17.1	30.4	131.6	1.30	4.3	13.0	4.2	6.7	0.602
TN-1	0.0	0.0	8.14	0.91	21.7	14.3	5.27	0.16	2.00	2.71	32.9	12.3	5.4	126.0	1.55	3.0	12.7	3.3	1.3	0.605
TN-2	0.0	0.0	8.47	0.46	19.2	14.3	4.36	0.25	0.26	3.27	16.8	16.5	6.2	5.6	0.90	2.3	5.9	3.8	1.1	0.139
TN-3	0.2	0.7	8.29	0.27	27.7	19.9	5.73	0.33	1.58	3.47	17.4	45.5	16.0	127.1	1.20	2.8	4.5	4.8	1.8	0.425
TN-4	0.0	0.0	8.45	0.35	23.2	14.9	6.02	0.36	1.91	2.48	16.7	15.8	10.8	140.3	2.20	3.7	7.4	10.0	4.8	0.394

#### *Greenhouse survey*

This experiment was done in greenhouse of Tianjin Soil and Fertilizer Institute. The treatments were listed in Table 3. The volume of pots was 300ml and 500ml. The pots were filled with 250ml and 400ml soil, respectively.

**Table 3.** Treatments of greenhouse survey and added nutrients doses

Soil sam- ple No.	Treatment	N	P	K			S	B	Cu	Fe	Mn		Mo	Zn	Total treatments
				1.0	0.5	0.25					1.0	0.5			
TO-1	OPT*	4	0	2			0	0	0	0	4.5		0	0	12
	Others*	0	4	0			4	4	4	4	0		4	4ck	
TO-2	OPT	4	0	8			0	0	0	0	6		0	0	12
	Others	0	4	0			4	4	4	4	0		4	4ck	
TO-3	OPT	4	0	4			0	0	0	0	4.5		0	0	12
	Others	0	4	0			4	4	4	4	0		4	4ck	
TO-4	OPT	4	1.5	2.5			0	0	0	0	6		0	0	12
	Others	0	0	0			4	4	4	4	0		4	4ck	
TN-1	OPT	4	3.5	12			0	0	0	0	6		0	3	14
	Others	0	0	0	6	3	4	4	4	4	0		4	0ck	
TN-2	OPT	4	3.5	8			3.5	0	2	4	6		0	3	13
	Others	0	0	0	4		0	4	0	0	0		4	0ck	
TN-3	OPT	4	3.5	2			0	0	1.5	4	8		0	3.2	13
	Others	0	0	0			4	4	0	0	0	4	4	0ck	
TN-4	OPT	4	3.5	2.5			0	0	0	4	7.5		0	1.5	13
	Others	0	0	0			4	4	4	0	0	3.8	4	0ck	

The unit of element added to soil; ml stock solution/400ml soil

\* OPT; recommended optimum treatment, ck; no adding nutrients;

\* \* Others; adding the same nutrients as in OPT except the testing nutrients.

The hybrid sorghum was used as indicator. Six plants were kept in each pot. The -N and ck treatments were irrigated with deionized water, and the others were irrigated with  $\text{NH}_4\text{NO}_3$  0.3g/L solution. The water was supplied by using a uncut cigarette filter (15 cm long). Each treatment was replicated four times and was randomly arranged. The growth period was from June 5 to July 25. The dry weight of aerial parts was measured. Results of greenhouse survey were listed in Table 4.

**Table 4.** Results of greenhouse survey and the deficient rank of nutrients

No.	TO-1		TO-2		TO-3		TO-4		TN-1		TN-2		TN-3		TN-4	
	T	RY	R	RY	R	RY	T	RY	R	T	RY	R	T	RY	R	T
1	OPT	100		100		100	OPT	100		OPT	100		OPT	100		OPT
2	-N	59	1	79	2	101	-N	69	1	-N	16	2	-N	20	2	-N
3	+P	105		95		107	-P	81	2	-P	11	1	-P	14	1	-P
4	-K	87	2	67	1	89	2	-K	100	-K	98		-K	85	4	-K
5	+S	108		103		82	+S	118		+S	107		-S	92	7	+S
6	+B	99		88		96	+B	99		+B	106		+B	94		+B
7	+Cu	89		119		101	+Cu	106		+Cu	107		-Cu	87	5	-Cu
8	+Fe	97		107		98	+Fe	90		+Fe	98		-Fe	74	3	-Fe
9	-Mn	99		82	3	81	1	-Mn	95	-Mn	135		-Mn	99		-Mn
10	+Mo	105		99		103	+Mo	88		+Mo	98		+Mo	105		+Mo
11	+Zn	72		96		109	+Zn	100		-Zn	69	3	-Zn	90	6	-Zn
12	ck	56		79		79	ck	64		$\frac{1}{2}$ K	100		$\frac{1}{2}$ K	99		$\frac{1}{2}$ Mn
13										$\frac{1}{4}$ K	87		ck	15		ck
14										ck	11					

T: treatment; RY: relative yield; R: the deficient rank of nutrients

## Results and discussion

### *Nutrient features of vegetable soils*

According to the critical levels suggested by Hunter(1984),we analysed the available nutrient contents in vegetable soils,and their features could be summarized as follows:

1. Nutrient accumulation was obvious in developed vegetable soil with planting ages more than 10 years,especially the phosphorus nutrient. The average content of available phosphorus was 127 ppm,which was 13 times of that in developing vegetable soil(planting age less than 5 years). Except for manganese,the average contents of copper,zinc,and iron were 5.85 ppm,21.95 ppm,and 12.93 ppm,which were 2,3 and 6 times of those in developing vegetable soils,respectively. Boron and Sulphur lightly accumulated.

2. The nutrient content and capacity were higher in developed vegetable soils. This could be seen from their high nutrient supplying potential. The average relative yield of check treatment was 69.5% in developed vegetable soil,on the contrary,22.75% in developing vegetable soil(Table 4).

3. Compared with developing vegetable soil,the developed vegetable soil had less calcium,but the relative conductance in developed vegetable soil was higher. This suggested that salt content increased.

4. The nitrogen,potassium,and manganese were deficient in both the developed and developing vegetable soils. The ratio of Mg/K increased,and the average value was 19.3 which was higher than the top critical level of 14(Table 2).

Shen Han(1990)reported that the nutrient accumulation sequence in farmland soil was  $N > P > K$ ,but it was  $P > N > K$  in vegetable soil. The obvious features of nutrient accumulation and transfer in vegetable soil in Beijing suburbs was high phosphorus accumulation, medium S,N accumulation; low calcium and chloride accumulation. However,potassium transferred actively. The available phosphorus content there was the highest in China. The difference between farmland soil and vegetable soil lay in the nitrogen uptake and utilized rate. The results of our study on the nitrogen utilized rates by some vegetables by using  $N^{15}$  showed that the mean nitrogen utilized rate was 28.68% (Table 5), soil residue was 30.07%,and the loss part was 41.25%. All of them were slightly different from that of field crops. However,the nitrogen sources were quite different. Vegetables took up about 34.61% nitrogen from fertilizer,and 65.37% from soil. On the contrary,field crops took up about 66.97% nitrogen from fertilizer and 33.03% from soil. These characteristics made the limiting factors and fertilization strategy different between developed and developing vegetable soils.

**Table 5.** Nitrogen utilized rates of some vegetables and field crops

Crops		Utilized rate(%)	Soil residue rate(%)	Loss (%)	Nitrogen sources	
					Fertilizer	Soil
Vegetable	Cucumber	30.80	20.58	48.62	50.28	49.72
	Tomato	27.37	16.07	56.56	63.46	36.54
	Califlower	24.82	37.50	37.68	23.63	76.37
	Chinese cabbage	36.09	24.32	39.59	22.49	77.51
	Kidney bean	24.34	51.86	23.80	13.19	86.81
	Average	28.68	30.07	41.25	34.61	65.39
Grain crops	Wheat	30.99	11.91	57.10	69.47	30.53
	Corn	28.90	12.10	59.00	47.72	52.28
	Rice	21.24	50.36	28.40	83.73	16.27
	Average	27.04	24.79	48.17	66.97	33.03

### Analysis on yield limiting factors in vegetable soils

The results of greenhouse survey (Table 4) suggested that in four sites of developing vegetable soils the average relative yield with  $-N$ ,  $-P$ ,  $-K$  treatment was 29.8%, 24.3% and 95.8%, respectively, in other words, the sequence of limiting factors was  $P, N$ ; but  $K$  had little effect on yield. In developed vegetable soil, the average relative yield with  $-N$ ,  $-P$ ,  $-K$  treatment was 73.3%, 97%, 85%, respectively. Nitrogen was the first important limiting factor, potassium was the second one, and phosphorus had little effect on yield. The degree of yield decrease owing to minus nutrient treatment was also quite different between developed and developing vegetable soils. The yield might decrease by 70% with OPT in developing vegetable soil, and by 20% with OPT in developed vegetable soil.

The soil in Tianjin suburbs is calcareous, pH value generally is higher than 8, and the available manganese is low. Absorption study results showed that the average extract value was only 11.06  $\mu\text{g/ml}$ , while available manganese addition value was 40  $\mu\text{g/ml}$ . When 80  $\mu\text{g/ml}$  of the available manganese was input to soil in site of Shui Gaozhuang, the extract was only 20.2  $\mu\text{g/ml}$ . So it is necessary to further research the soil manganese adsorption and fixation and manganese fertilizer effect. The greenhouse survey showed that the relative yield of eight samples with the  $-Mn$  treatment was 81.5%. Therefore, it would become one of the yield limiting factors. Micronutrients  $Zn, Fe, Cu$  might also be the yield limiting factors in developing vegetable soil. In some samples, the  $-Zn, -Fe, -Cu$  treatment decreased the yield 31, 26, 13 percent, respectively (Table 4).

### Budget of $N, P, K$ in vegetable soil

According to the existing fertilization in vegetable soil in Tianjin, we researched the balance of the  $N, P, K$  nutrients input-output on both farmland soils and vegetable soils with different planting ages (Table 6).

**Table 6.** Budget of  $N, P, K$  in vegetable soil and farmland soil

Soil	Location	Cropping system	Planting age	Input (kg/ha) (fertilizer, seed, irrigation, rainfall)			Output (kg/ha) (yield of vegetable or grain crop; loss of fertilizer)			$\pm$			Percentage of input to output		
				N	P	K	N	P	K	N	P	K	N	P	K
Veg. soil	Yanliuqin	Cucumber	100	840.0	240.0	360.0	763.5	436.5	715.5	+76.5	-196.5	-355.5	110.0	55.0	50.3
		Chinese cabbage													
	Baitangkou	Chinese cabbage	50	793.5	111.0	225.0	765.0	282.0	442.5	+28.5	-171.0	-217.5	103.7	39.4	50.8
		spinach eggplant													
	Xinlizhun	Chinese cabbage	50	712.5	90.0	135.0	562.5	391.5	496.5	+150.0	-301.5	-361.5	126.7	23.0	27.2
		tomato													
Farm. soil	Tianmu	Celery spinach	40	1018.5	450.0	675.0	643.5	606.0	714.0	+375.0	-156.0	-39.0	158.3	74.3	94.5
	Yanliuqin	Eggplant	20	870.0	300.0	451.5	742.5	342.0	637.5	+127.5	-42.0	-187.5	117.2	87.7	70.8
	Average			847.5	238.5	369.0	696.5	411.0	601.5	+151.5	-174.0	-232.5	123.2	55.9	58.7
	Dabeijian	Spring wheat		354.0	91.5	136.5	367.5	114.0	147.0	-10.5	-22.5	-10.5	97.1	80.3	92.9
		-late rice													
	Cinamon area	Undersowing of wheat and corn		310.5	22.5	1.5	333.0	63.0	177.0	-22.5	-40.5	-175.5	93.2	35.7	0.8
Farm. soil	Yuanzhen	Undersowing of wheat and corn		226.5	36.0	136.5	250.5	106.5	331.5	-24.0	-70.5	-195.0	90.4	33.8	41.2
	Huanzhuangwa	Spring corn		42.0	12.0	1.5	72.0	30.0	99.0	-30.0	-18.0	-97.5	58.3	40.0	1.5
	Average			234.0	40.5	69.0	255.0	78.0	189.0	-22.5	-37.5	-120.0	84.8	47.5	34.1

The results showed that nitrogen was surplus in vegetable soil and slightly deficient in farmland soil. However, with notable decreasing of organic manure application, phosphorus

and potassium, especially the latter are becoming deficient not only in vegetable soil, but also in farmland soil. The soil nutrient survey in Tianjin shows that in last decade the available phosphorus content increases while the available potassium content decreases, especially in the high yield demonstration areas, where the available potassium was decreased by 30—40%. If the existing fertilization situation of highest nitrogen, higher phosphorus and low potassium is not changed, the effect produced by it will make us fail to achieve maximum yield and economic return and good quality. In a word, we should pay much attention to balance fertilization.

#### *Some suggestion on balance fertilization in vegetable soil*

The field trials in last two years had proved the feasibility of using systematic approach of soil nutrient status to analyse the yield limiting factors and recommend scientific fertilization. The results of 9 field trials on Chinese cabbage, tomato, water melon, celery tallied with the results of greenhouse survey (other two papers had given results and discussion in detail). So the systematic approach, including routine analysis, absorption test and greenhouse survey, should be recommended to apply on a large scale. The comprehensive researches on soil nutrient status in different vegetable soils gave us to understand the balance fertilization in vegetable soils.

1. Economic fertilization and nutrient balance should be concerned with in developed vegetable soil. This is the key to reduce cost, increase yield and improve quality. Blind and heavy application of fertilizer without careful consideration of features of developed vegetable soil can only result in fertilizer waste, water pollution, vegetable quality deterioration and make insect pest more severe.

The field trial has suggested that the proper supplying of nitrogen and potassium and their suitable ratio are important, and allocation of potash in vegetable rotation system also plays a important role. Excess application of nitrogen will decrease the yield (Table 7, 8, 9).

**Tables 7.** Results of trial on Chinese cabbage in Wuxinzhuang, Baodi County

Treatment	Block yield (tons/ha)				$\bar{x}$ (tons/ha)	Yield increase		Net income US \$ /ha
	I	II	III	IV		(tons/ha)	%	
N <sub>225</sub> P <sub>75</sub> Mn <sub>30</sub>	128	126	122	127	126	10	8.6	102
N <sub>225</sub> P <sub>75</sub> K <sub>112.5</sub> Mn <sub>30</sub>	133	125	134	132	131	15	12.9	190
N <sub>225</sub> P <sub>75</sub> K <sub>225</sub> Mn <sub>30</sub>	138	142	131	144	139	23	19.8	361
N <sub>375</sub> P <sub>75</sub> Mn <sub>30</sub>	120	126	131	119	124	8	6.9	17
N <sub>375</sub> P <sub>75</sub> K <sub>112.5</sub> Mn <sub>30</sub>	131	133	126	128	130	14	12.1	132
N <sub>375</sub> P <sub>75</sub> K <sub>225</sub> Mn <sub>30</sub>	132	138	143	126	135	19	16.4	219
N <sub>375</sub> P <sub>75</sub> K <sub>225</sub>	128	126	133	137	131	15	12.9	112
ck	108	125	114	116	116		0	

L. S. D(0.05)=8.14 L. S. D(0.10)=6.73

2. The key to increase yield in developing vegetable soil is the input of chemical fertilizers. The field trial on Chinese cabbage in Shui Gaozhuang (Table 10) shows that the interaction between nitrogen and potassium is quite obvious, and high yield and economic return can be gained if the nutrients are supplied in balance. Therefore, Attention should be paid to the input of chemical fertilizers and their balance in developing vegetable soil. In ad-

**Tables 8.** Results of trial on celery in Lilou

Treatment	Block yield (tons/ha)				$\bar{x}$ (tons/ha)	Yield increase		Net income US \$ /ha
	I	II	III	IV		(tons/ha)	%	
$N_{225}P_{45}K_{135}Mn^{*}Cu^{**}84$	88	87	82	85	85	8	10.4	992
$N_{225}P_{45}K_{90}MnCu$	87	83	93	76	85	8	10.4	1003
$N_{225}P_{45}K_{45}MnCu$	79	82	81	77	80	3	3.9	308
$N_{225}P_{45}K_{135}Cu$	78	83	82	77	80	3	3.9	288
$N_{225}P_{45}K_{135}Mn$	82	85	85	88	85	8	10.4	992
ck	77	78	78	75	77		0	

L. S. D(0.05) = 4.8

\* Mn 0.1%  $MnSO_4$  3 tons/ha, spray three times      \*\* Cu: 0.03%**Tables 9.** Results of trial on tomato in Linlou

Treatment	Block yield (tons/ha)				$\bar{x}$ (tons/ha)	Yield increase		Net income US \$ /ha
	I	II	III	IV		(tons/ha)	%	
$N_{225}P_{45}K_{112.5}MnCu$	47.8	44.5	46.2	45.8	46.1	4.6	11.1	435
$N_{225}P_{45}K_{56.25}MnCu$	46.8	47.5	47.5	45.2	46.8	5.3	12.8	534
$N_{225}P_{45}MnCu$	48.8	46.8	49.2	49.0	48.5	7.0	16.9	757
$N_{225}P_{45}K_{112.5}Cu$	45.2	42.5	44.5	45.0	44.3	2.8	6.7	215
$N_{225}P_{45}K_{112.5}Mn$	47.0	45.0	45.8	44.0	45.5	4.0	9.6	363
ck	44.2	39.5	40.5	41.8	41.5	0	0	0

L. S. D(0.05) = 1.63    L. S. D(0.10) = 1.34

**Tables 10.** Results of trial on Chinese cabbage in Shuigaozhuang

Treatment	Block yield (tons/ha)				$\bar{x}$ (tons/ha)	Yield increase		Net income US \$ /ha
	I	II	III	IV		(tons/ha)	%	
$N_{150}P_{112.5}Mn_{30}$	84	90	92	80	87	0	0	-108
$N_{150}P_{112.5}K_{112.5}Mn_{30}$	98	94	93	96	95	8	9.2	62
$N_{150}P_{112.5}K_{225}Mn_{30}$	124	124	126	116	123	36	41.4	684
$N_{300}P_{112.5}Mn_{30}$	112	116	122	110	115	28	32.2	481
$N_{300}P_{112.5}K_{112.5}Mn_{30}$	133	134	132	128	132	45	51.7	877
$N_{300}P_{112.5}K_{225}Mn_{30}$	149	152	146	144	148	61	70.1	1.218
$N_{450}P_{112.5}Mn_{30}$	138	141	135	134	137	50	57.5	958
$N_{450}P_{112.5}K_{112.5}Mn_{30}$	146	149	144	142	145	58	66.8	1.101
$N_{450}P_{112.5}K_{225}Mn_{30}$	165	169	163	164	165	78	89.7	1.553
ck	82	90	92	84	87			

L. S. D(0.05) = 4.39

dition, supply of organic manure should be increased so as to improve soil fertility and nutrient potential.

## Conclusion

1. The diagnosis on 12 nutrients in different vegetable soils by using systematic approach shows that N, K, Mn are the major yield limiting factors in developed vegetable soil, and P.

N, Mn are the major ones in developing vegetable soil. Zn, Fe, Cu may be the yield limiting factors in developing vegetable soil.

2. The soil fertility features are quite different between developed and developing vegetable soils. The developed soil is characterized by the high phosphorus accumulation, medium accumulation of micronutrients, such as Zn, Fe, and Cu. In addition, it has higher nutrient content, high capacity and nutrient supply potential, which are the base for stable high yield of vegetables.

3. Balance fertilization in vegetable soils displays clearly that economic fertilization is important in developed vegetable soil, and scientific combination of chemical fertilizers is important in developing one.

4. The systematic approach of soil nutrient status has yielded good results in the vegetable soil study. It should be widely used.

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