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Fertilization Status and Soil Nutrient Condition in Some Asparagus Production Regions of Zhejiang Province

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Abstract Asparagus is delicious, with rich nutrition, and it is one of main economic crops in Zhejiang Province. In this paper, by investigating fertilization situations of farmers in several asparagus production regions (Fuyang, Pinghu, Changxing and Cixi) and soil nutrient condition of asparagus garden with different plantation years, fertilization status and nutrient condition of asparagus garden were described, and fertilization suggestion was proposed, which aimed to guide scientific fertilization of asparagus and promote healthy development of industry.

Key words Asparagus, Fertilization, Soil nutrient

1 Introduction

Asparagus is perennial herb of *Asparagus* L., Liliaceae, and its tender stem is used for food, which is delicious and nutritious. It also has the effects of resisting tumour, resisting oxidation and reducing blood sugar, and is nutrition and health care type of high-grade vegetable favored by consumers, which is called "the king of vegetables" and one of "ten famous dishes in the world". In recent years, asparagus industry develops quickly in China, and China has becomes the largest producer and exporter of asparagus in the world. Asparagus plantation of Zhejiang Province started from the 1970s, and scale production of asparagus in Zhejiang Province was the earliest in mainland. Its main product was white asparagus, which was taken as the raw material of processing can, and the product was exported to Europe and the United States[1]. Since 1992, the product in Zhejiang Province was dominated by green asparagus, which supplied domestic market or exported via cold storage and quick freezing. In recent years, asparagus industry of Zhejiang Province vigorously develops, and plantation area of whole province breaks through 3 333 ha, especially protected cultivation has become an important source of farmer income increase in some areas and new rural economic growth point.

In this paper, by investigating fertilization situations of farmers in several asparagus production regions (Fuyang, Pinghu, Changxing and Cixi) and soil nutrient condition of asparagus garden with different plantation years, fertilization status and nutrient condition of asparagus garden were described, which aimed to guide scientific fertilization of asparagus and promote healthy development of industry.

2 Materials and methods

2.1 Investigation of fertilization situation To understand current fertilization condition of asparagus plantation process, 11 growers in Changxing and Pinghu were investigated, and fertilization type, amount and times of organic fertilizer and chemical fertilizer in one year were investigated and recorded.

2.2 Soil nutrient condition Soil at 0 - 20 cm of plough layer in asparagus garden with different plantation years in different was sampled, and total nitrogen, organic matter, available phosphorus, available potassium, and pH in soil sample were measured.

Organic matter used potassium dichromate titration; total nitrogen used sulfuric acid-potassium sulphate-copper sulphate boiling steam titration; available phosphorus used sodium bicarbonate extraction-molybdenum antimony colorimetric assay; available potassium used ammonium acetate extraction-flame photometer method; pH used acidity meter method. Excel software was used for data analysis and treatment.

3 Results and analyses

3.1 Investigation and analysis of asparagus fertilization situation Seen from Table 1, fertilization situations of different asparagus planters were different. Firstly, fertilization amount of organic fertilizer had larger difference, and the input of organic fertilizer by farmer was directly related to variety and price of organic fertilizer. For example, sites 3 and 5 used commercial organic fertilizer, and annual fertilization amount was 5.25 t/ha; sites 4 and 8 used sheep manure and chicken manure, and annual fertilization amount was 55 - 75 t/ha; sites 9 - 11 used mushroom residue, and annual fertilization amount was 34.5 - 60 t/ha. In general, the price of commercial organic fertilizer was 600 - 1 000 yuan/t, which was higher, and its dosage was less. Sheep manure, chicken manure and mushroom residue were mostly obtained nearby, and some organic fertilizers could be obtained freely, while the price of some organic fertilizers was tens of yuan per ton, which was cheap, with larger fertilization amount.

Secondly, at input aspect of chemical fertilizer, chemical fer-

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tilizer variety was dominated by conventional three-element compound fertilizer, urea and superphosphate. When using organic fertilizer in base fertilizer, compound fertilizer and phosphate fertilizer were used, while compound fertilizer or urea was used in top dressing. As shown in Table 2, different farmers had different input amounts of chemical fertilizer, and average fertilization amount was 1 341 kg/ha, with coefficient of variation of 46%. The maximum fertilization amount was 2 835 kg/ha, while the minimum fertilization amount was 742.5 kg/ha, and the maximum was 3.8 times of the minimum. Input proportion of N, P, K was also different. Some farmers had a preference for nitrogen fertilization, such as sites 2, 5, 11, and input proportion of nitrogen fertilizer was greatly larger than that of phosphorus fertilizer and potassium fertilizer. Some farmers had a preference for phosphorus fertilizer, such as sites 4, 7, 10, and input proportion of phosphorus fertilizer was higher. Coefficients of variations of N, P, K inputs were respectively 47%, 67% and 59%. Fertilization times also had larger difference, which varied from 4 to 16 times.

Table 1 Investigation result of fertilization situation by farmer

No.	Organic fertilizer//t/ha	Chemical fertilizer						Fertilization times
		Variety	Dosage//kg/ha	Variety	Dosage//kg/ha	Variety	Dosage//kg/ha	
Site 1	60.00	Compound fertilizer	1 650					7
Site 2	30.00	Compound fertilizer	1 950	Urea	713			13
Site 3	5.25	Compound fertilizer	2 850	Urea	675			16
Site 4	75.00	Compound fertilizer	1 950	Calcium superphosphate	1 275			6
Site 5	5.25	Compound fertilizer	1 875	Urea	1 875			11
Site 6	15.00	Compound fertilizer	1 650	Urea	525			7
Site 7	21.00	Compound fertilizer	5 325	Urea	675	Calcium superphosphate	750	13
Site 8	56.25	Compound fertilizer	1 800	Urea	300			10
Site 9	55.50	Compound fertilizer	1 500	Urea	693			4
Site 10	34.50	Compound fertilizer	3 600	Water soluble fertilizer	446			12
Site 11	60.00	Compound fertilizer	750	Urea	960			6

Note: Organic fertilizer mainly contained mushroom residue, sheep dung, rabbit dung, rapeseed cake, commercial organic fertilizer.

Table 2 Input amount of chemical fertilizer and proportion of N, P, K

No.	Total fertilization amount//kg/ha	N//kg/ha	P//kg/ha	K//kg/ha
Site 1	742.5	247.5	247.5	247.5
Site 2	1 205.3	620.3	292.5	292.5
Site 3	1 593.0	738.0	427.5	427.5
Site 4	1 094.3	292.5	879.0	292.5
Site 5	1 706.3	1 143.8	281.3	281.3
Site 6	984.0	489.0	247.5	247.5
Site 7	2 834.3	1 109.3	926.3	798.8
Site 8	948.0	408.0	270.0	270.0
Site 9	993.8	543.8	225.0	225.0
Site 10	1 878.4	611.3	575.6	691.5
Site 11	779.1	554.1	112.5	112.5
Mean	1 341.7	614.3	407.7	353.3
Standard deviation	622.2	290.8	272.0	208.5
Coefficient of variation//%	46.0	47.0	67.0	59.0

Thirdly, at fertilization manner, topdressing method of most farmers was still dominated by surface spraying or ditch fertilization in Changxing, Fuyang and Cixi. Although spraying, drip irrigation facilities were installed in some gardens, there was not matching fertilization equipment, and they were mainly used for irrigation. In recent two years, under the guide of agricultural technicians, some farmers started to install fertilization equipment, thereby realizing top dressing of integrated water and fertilizer. Integrated water and fertilizer technology of asparagus in Pinghu region developed earlier, with higher popularity. Most of farmers have used the integrated water and fertilizer manner for top dressing, which was dominated by urea, such as sites 9 and 11, and some farmers used water soluble special formula fertilizer, such as site 10.

3.2 Comparison between nutrient demand rule of asparagus and actual fertilization situation According to the report, asparagus producing 1 000 kg of tender stem needed absorbing 16 kg of N[2], 4.5 kg of P[3] and 15 kg of K[4-5], and N∶P∶K was about 1∶0.45∶1. Calculated by target yield of 22.5 – 27.0 t/ha, it needed 810 – 975 kg of nutrient.

According to fertilizer demand rule of asparagus and conventional asparagus yield, 900 kg/ha of nutrient demand was counted, and profit and loss amount between actual chemical fertilizer input and nutrient demand at each investigation site was shown as Fig. 1. At sites 1 and 11, chemical fertilizer input was less than

nutrient demand, showing as deficit. At other sites, chemical fertilizer input was more than nutrient demand, showing as surplus. Among them, the surpluses amount at sites 2, 3, 5, 7 and 10 reached 300 – 1 935 kg/ha and were larger, which accounted for 45% of total investigation site number. It was clear that excessive fertilization condition in asparagus plantation process was general.

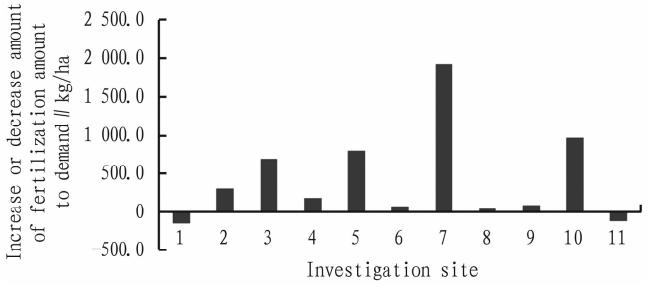

Fig. 1 Comparison between actual fertilization amount and demand

3.3 Soil nutrient condition of asparagus garden Soil of asparagus garden of Fuyang, Cixi, Pinghu and Changxing in different years was sampled and detected, and soil nutrient condition of each region was shown as Table 3. Seen from Table 3, pH of asparagus garden was between 4.21 – 7.41. Overall, acid soil was dominant, and more than 60% of soil was acidic or strongly acidic. Among them, pH 6.5 – 7.5 of neutral soil accounted for 19%, pH 5.5 – 6.5 of slightly acidic soil accounted for 19%, pH 4.5 – 5.5 of acidic soil accounted for 50%, pH ≤4.5 of strongly acidic soil accounted for 11% (Fig. 2).

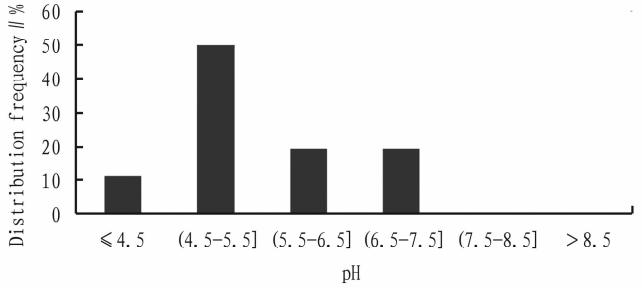

Fig. 2 Distribution frequency of soil pH in asparagus garden

Table 3 Soil nutrient condition and plantation years of asparagus garden

Sampling site	No.	pH	Organic matter // g/kg	Available phosphorus // mg/kg	Available potassium // mg/kg	Total nitrogen // g/kg	Plantation years // a
Fuyang	1	7.41	35.20	279.82	285.9	2.19	2
	2	5.88	28.30	273.83	177.4	1.46	2
	3	5.63	24.70	31.22	187.3	1.57	2
	4	7.21	27.70	434.83	68.8	1.48	2
	5	5.56	32.60	214.80	171.2	1.99	5
	6	6.53	30.80	189.56	150.7	1.97	2
	7	4.86	27.40	365.66	345.4	1.70	5
	8	5.06	22.70	67.72	140.5	1.39	2
	9	5.41	22.90	504.12	298.6	1.40	5
	10	4.68	21.10	130.19	137.8	1.32	5
	11	4.96	35.50	361.58	216.9	1.99	5
	12	4.34	21.50	230.72	256.3	1.42	5
	13	5.07	25.20	72.60	202.0	1.45	2
	14	4.48	26.80	260.04	171.2	1.58	5
	15	5.39	32.90	345.98	557.2	2.34	8
	16	–	–	507.90	696.0	1.43	8
	17	–	–	452.40	459.0	1.42	8
	18	–	–	1 054.20	755.0	1.80	13
	19	–	–	804.10	578.0	1.78	13
	20	–	–	909.40	520.0	1.64	13
	21	–	–	697.70	489.0	1.60	13
	22	–	–	722.00	933.0	1.70	23
	23	–	–	886.70	1 288.0	1.81	23
	24	–	–	818.00	1 229.0	1.80	23
	25	–	–	1 072.60	1 792.0	1.88	23
Cixi	26	6.96	8.12	35.30	405.0	1.04	2
Pinghu	27	5.14	53.65	1 324.50	1 148.0	–	9
	28	4.21	61.56	1 096.95	1 127.0	–	9
	29	4.45	66.04	717.17	1 337.0	–	9
	30	6.20	100.43	1 407.35	1 584.0	–	9
	31	6.34	113.00	780.00	3 274.0	7.64	15

(To be continued)

(Continued)

Sampling site	No.	pH	Organic matter // g/kg	Available phosphorus // mg/kg	Available potassium // mg/kg	Total nitrogen // g/kg	Plantation years // a
	32	6.72	127.00	501.50	3 131.00	8.00	15
	33	6.22	95.10	783.00	3 274.00	6.54	15
Changxing	34	4.75	42.45	145.95	420.00	–	3
	35	4.65	32.06	67.91	358.00	–	3
	36	5.40	38.43	67.14	320.00	–	3
	37	4.65	36.03	219.43	640.00	–	5
	38	4.95	39.23	128.31	492.00	–	3
	39	5.68	33.34	30.06	159.00	–	1
	40	6.56	47.87	119.77	435.00	–	3
	41	6.63	27.99	56.24	385.00	–	3
	42	5.10	44.67	192.51	536.00	–	5
Mean	–	–	43.20	460.97	741.22	2.25	–
Standard deviation	–	–	28.15	383.35	814.94	1.81	–
Coefficient of variation	–	–	0.65	0.83	1.10	0.80	–

At sampling site of asparagus garden, average organic matter, total nitrogen, available phosphorus, available potassium contents were respectively 43.2 g/kg, 2.25 g/kg, 460.97 mg/kg and 741.22 mg/kg, which was all significantly higher than average level of soil nutrient in arid land of Zhejiang Province. Among them, average available phosphorus content was 3.6 times of mean level of arid land in Zhejiang Province and 17.6 times of mean level of paddy field, and the maximum reached 1 407.35 mg/kg. Average available potassium content was 5 times of mean level of arid land in Zhejiang and 9.7 times of average level of paddy level, and the maximum reached 3 278 mg/kg. According to the observation, there existed obvious secondary salinization phenomenon in asparagus shed of some regions(Fig.3). Nutrient change at each sampling site also had great difference. Coefficients of variations of organic matter, available phosphorus, available potassium and total nitrogen were respectively 65%, 83%, 110% and 80%.

Fig.3 Secondary salinization phenomenon of asparagus garden

3.4 Relationship between soil nutrient content of asparagus garden and plantation years The sample of Fuyang District was used, and correlation test between total nitrogen, organic matter, available phosphorus, available potassium, pH and plantation years was conducted. The result showed that the correlation between total nitrogen, organic matter and plantation years was weaker, and their correlation coefficients were respectively 21.2% and 10.4%. Available phosphorus and available potassium showed significantly positive correlation with plantation years, and their coefficients were respectively 84.9% and 92.0%. The longer the plantation years, the higher the contents of available phosphorus and available potassium. pH showed negative correlation with plantation years, and correlation coefficient was −53.9%. The longer the plantation years, the lower the soil pH, and soil had an acidification tendency.

3.5 Conclusions (i)Fertilization of asparagus garden had larger difference among farmer individuals. The application of organic fertilizer was arbitrary, and the dosage in some areas reached 60−75 t/ha and was large. Fertilization structure of chemical fertilizer was single, and its fertilization amount was large. Fertilization manner in most areas was dominated by surface spraying or ditch fertilization, with low fertilizer use rate, which consumed labor.

(ii)Total nitrogen, organic matter, available phosphorus and available potassium of soil sample in asparagus garden were all higher than mean levels of paddy field and other arid land in Zhejiang Province. Especially accumulation amounts of available phosphorus and available potassium were higher, and they had further accumulation trend with plantation years increased. pH was lower, and most of soil showed acidity or strong acidity, and there was acidification trend with plantation years increased. Obvious secondary salinization of soil appeared in some asparagus gardens.

4 Discussions

For fertilization status and soil nutrient condition of asparagus, below suggestions are proposed. Firstly, application of organic fertilizer should be safe. Organic fertilizer contains comprehensive nutrient and long fertilization effect, could improve soil structure, is favorable for the development of asparagus root system, and improve water conservation and fertility protection ability of soil. Therefore, the organic fertilizer could significantly increase yield and improve quality. But mass application of organic fertilizer must guarantee the safety. It is suggested detecting the quality of organic fertilizer and heavy metals before fertilization to guarantee soil safety. Additionally, when farmers voluntarily applies farmyard manure, sheep manure, and chicken manure, the composting treatment must be conducted, which could not only skill the carried pathogenic bacteria but also avoid causing seedling burnt. Secondly, chemical fertilizer should be rationally applied. Excessive application of chemical fertilizer is easy to induce soil harden-

ing, acidification and secondary salinization, which affects root system growth and inoculation of tender stem. It is suggested that nutrient content is supplied according to the demand to avoid excessive accumulation of nutrient in soil sample. Meanwhile, it should improve fertilization structure and rationally match nutrient proportion according to absorption rule of N, P, K by asparagus, which could not only save unnecessary nutrient input but also maintain supply balance and optimize soil environment. Thirdly, it should improve fertilization manner. Traditional surface spraying and ditch fertilization have larger disadvantages. On the one hand, fertilizer nutrient mainly concentrates in soil surface and is difficult to be absorbed and used by deep root system, causing large application of fertilizer, low use rate, nutrient accumulation of soil surface and soil environment deterioration. On the other hand, artificial fertilization consumes labor, with high artificial cost and low efficiency, which affects production level. It is suggested improving toward integrated water and fertilizer, which could not only save labor, improve efficiency, save cost but also realize coupling of water and fertilizer, improve nutrient absorption by root, improve fertilizer use rate, decrease fertilizer input, and maintain benign health of soil environment.

Specific fertilization case suggestions were as below. Base fertilizer applied after land preparation: soil was ploughed in 10 – 15 d before transplantation, and 45 cm of plantation ditch was dug. There were four sheds of 6 m and five sheds of 8 m. 2 000 – 3 000 kg of decomposed organic fertilizer, 30 – 40 kg of three-element compound fertilizer, 50 kg of calcium magnesium phosphate fertilizer were applied in the ditch per 667 m^2, and then plantation ditch was covered by soil.

Water and fertilizer management: 25 kg of three-element compound fertilizer was applied in the ditch per 667 m^2 in 7 – 10 d before spring mother stem maintained, and 10 – 15 kg of three-element compound fertilizer was applied per 667 m^2 after maintaining stem for one month, namely spring mother stem growing into the plant. During harvest period of summer asparagus, once top dressing was conducted in prior period with 20 d of interval time and latter period with 15 d of interval time. The dose was 20 – 30 kg of three-element compound fertilizer per 667 m^2, with 2 – 3 times. After drawing spring mother stem, 25 kg of three-element compound fertilizer was applied in the ditch before maintaining autumn mother stem. After maintaining autumn mother stem, 15 – 20 kg of three-element compound fertilizer per 667 m^2 was added at early stage with the interval of 15 d according to plant growth, with 2 – 3 times. Once leaf fertilizer containing potassium could be sprayed with the interval of 7 – 10 d at middle and latter periods. Organic fertilizer could be used in middle and last dekads of December after pulling rod and cleaning garden in winter, and 1 500 kg of decomposed organic fertilizer and 30 – 50 kg of three-element compound fertilizer were applied in the ditch per 667 m^2. For the land lacking middle and trace elements, such as calcium, boron, zinc and molybdenum, it should notice the combined application of fertilizer before maintaining stem.

It is advocated using drip irrigation for simultaneous irrigation of water and fertilizer. During maintaining periods of spring and autumn mother stems, 1 – 2 times of water soluble fertilizer with more nitrogen was used by drip irrigation, and the dosage was 6 – 8 kg/667 m^2, once per 10 days. Water soluble fertilizer was used during summer and autumn asparagus harvest periods, and once high nitrogen type and twice high nitrogen type alternately used. 6 – 8 kg of fertilizer per 667 m^2 was used per 10 – 15 d, with 10 – 12 times in total, and fertilization concentration of drip irrigation was 0.2% – 0.5%. During the period, it was not necessary to apply compound fertilizer at the same time.

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