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Effect of Combined Application of Boron and Molybdenum Microelement Fertilizer on Cowpea Yield and Quality

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Abstract Through field plot experiment, we research the influencing factors of cowpea yield and quality after applying boron and molybdenum microelement fertilizer. Results show that the application of boron and molybdenum microelement fertilizer can significantly increase the yield and improve the quality of cowpea. Compared with the control, yield per mu increases by 5.08 – 18.86%; N content increases by 4.27% – 11.28%; P content increases by 2.13% – 13.57%; K content increases by 2.00% – 18.48%; crude protein increases by 4.16% – 19.94%; vitamin C increases by 2.71% – 11.79%; nitrate content decreases by 5% – 15%. Besides, it is better to combine boron with molybdenum than to use each of them separately.

Key words Boron and molybdenum microelement fertilizer, Cowpea, Yield and quality

1 Introduction

With the improvement of people's living standards and international agricultural market competition, people place a higher demand on the quality of vegetables, especially health standards. Boron and molybdenum are micronutrient elements indispensable for the normal growth and development of plants. Vegetables are crops having preference for trace elements, especially boron. If without boron fertilizer, crops are easy to die, stems and petioles get brittle, and it also leads to flower underdevelopment and low fruition rate[1]. Applying boron fertilizer can improve nutrition for rape leaves, increase plant height and number of branches, avoid low fruition rate of rape, thereby increasing production[2]. Vegetables require very little molybdenum, but molybdenum is a very important trace element. Molybdenum can promote the development of legume roots, cause broad and deep root distribution, and increase root absorption area; increase nodule number, volume and enhance nitrogen fixation capability. Applying molybdenum is conducive to increasing chlorophyll content, promote plant photosynthesis, and improve the formation and transformation of carbohydrates[3-4]. When it lacks molybdenum, nitrate is excessively accumulated in plants; the number of amino acids and proteins is significantly reduced; the plant chloroplast structure is destroyed, the intensity of photosynthesis is reduced, and chlorophyll and reducing sugar content is reduced[5-7]. Du Yingqiong *et al.* find that the combined application of boron and molybdenum can significantly increase chlorophyll content and photosynthetic rate of peanut leaves, improve plant's dry matter accumulation, and thus significantly improve peanut production[8]. However, in the hot and humid laterite soil conditions of Hainan, there are few reports about the effect of combined application of boron and molybdenum on leguminous vegetable yield and quality. The aim of this study is to explore the effect of balanced application of nitrogen, phosphorus and potassium, and combined application of boron and molybdenum microelement fertilizer on cowpea yield and quality under the hot and humid laterite soil conditions in Hainan, in order to find high-yielding, high-quality and high-efficiency fertilization method, and provide some theoretical basis for the development of pollution-free vegetables in Hainan.

2 Materials and methods

2.1 Experimental design The experimental site is No. 8 test base of Topical Crops Genetic Resources Institute, Chinese Academy of Tropical Agricultural Sciences. The previous crop is bitter gourd, and the soil physical and chemical properties are as follows: organic matter content of 20.39g/kg; alkali-hydrolyzable nitrogen content of 87.6 mg/kg; available phosphorus content of 33.5 mg/kg; available potassium content of 21.8 mg/kg; available boron content of 0.39 mg/kg; available molybdenum content of 0.11 mg/kg. The test crop is cowpea, and the variety is Dabaoyoubai 1 (origin: Guangdong Fan Yuanhe Seed Company). The experiment includes six treatments, and uses randomized block design, repeated three times. The plot area is 6 m^2. (i) Seed dressing with boron and molybdenum microelement fertilizer (A); (ii) application of boron and molybdenum microelement fertilizer at the seedling and early flowering stages (B); (iii) seed dressing with boron fertilizer (C); (iv) seed dressing with molybdenum fertilizer (D); (v) non-application of boron and molybdenum microelement fertilizer (E); (vi) control (only spraying water) (CK).

2.2 Experimental management (i) Basal fertilizer. 5 kg of potassium chloride and 30 kg of superphosphate, as basal fertilizer, are applied once, that is, 0.04 kg of potassium chloride fertilizer and 0.26 kg of calcium, magnesium, phosphate fertilizer are applied in each plot. (ii) Dressing. 10 kg of urea per mu is ap-

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plied: 20% as fertilizer for seed bed; 30% as fertilizer for vines; 50% as fertilizer for flower and legumen. (iii) Concentration. Urea (1%); boron fertilizer (0.15%); molybdenum fertilizer (0.02%). (iv) Application rate of microelement fertilizer. 50 kg of fertilizer is sprayed per mu (667 m^2), and the stems and leaves are wetted. (v) Spraying time of microelement fertilizer. Boron and molybdenum microelement fertilizer is sprayed after 16:00, and it is necessary to extend the wetting time of fertilizer liquid on vegetable leaf as long as possible, in order to promote absorption and improve fertilizer spraying effect.

2.3 Analysis methods and data processing N content is determined using Kjeldahl determination method; P content is determined using Mo-Sb colorimetric method; K content is determined using flame photometry; vitamin C content is determined using 2, 6 dichloro-indophenol titration method; soluble sugar content is determined using Anthrone colorimetry; nitrate content is determined using UV spectrophotometry; crude protein content is determined using semi-micro Kjeldahl nitrogen determination method; molybdenum content is determined using oxalic acid-ammonium oxalate extraction-thiocyanate colorimetry; boron content is determined using curcumin colorimetric method. Duncan method in SPSS16.0 is used for multiple data comparison, and cowpea yield is obtained based on summation of yield in different harvesting time.

3 Results and analysis

From the results in Table 1, it is found that the fruit length, fruit weight, amount of seed in plot and thousand kernel weight under each treatment contribute more to yield increase than under the control. Fruit length increases the yield by 10.26 – 27.89%; fruit weight increases the yield by 3.07 – 21.46%; the amount of seed in plot increases the yield by 1.81 – 12.03%; thousand kernel weight increases the yield by 3.66 – 13.92%. In terms of the contribution to yield increase, the treatments are in the order of application of boron and molybdenum microelement fertilizer at the seedling and early flowering stages > seed dressing with boron and molybdenum microelement fertilizer > seed dressing with boron fertilizer > seed dressing with molybdenum fertilizer > non-application of boron and molybdenum microelement fertilizer > control. However, the application of microelement fertilizer requires more labor hours and fertilizers, and from economic point of view, Treatment A is feasible. The results in Table 2 show that cowpea pod number is largest and plot yield and total yield are highest under B, followed by A and C. In terms of the contribution to yield increase, the treatments are in the order of application of boron and molybdenum microelement fertilizer at the seedling and early flowering stages > seed dressing with boron and molybdenum microelement fertilizer > seed dressing with boron fertilizer > seed dressing with molybdenum fertilizer > non-application of boron and molybdenum microelement fertilizer > control. Compared with the control, the pod number in the plot increases the yield by 4.43 – 16.92%, the plot yield increases by 5.11 – 18.89%, and total yield increases by 5.08 – 18.86%. The study also finds that there are no significant differences in plot pod number, plot yield and total yield between Treatment A and B, while there are highly significant differences between Treatment A, B, and Treatment C, D, E, F, indicating that the combined application of boron and molybdenum microelement fertilizer can significantly improve the yield of cowpea. As shown in Table 3, it is found that the N, P, K content under various treatments is increased compared with the control. N increases by 4.27 – 11.28%; P increases by 2.13 – 13.57%; K increases by 2.0 – 18.48%. There is no significant difference in the content between Treatment A and B, between C and D, while there is a significant difference in N, P, K content between all treatments and the control. This indicates that the fertilization can increase cowpea uptake of N, P, K; applying microelement fertilizer can promote cowpea uptake of nutrients; the combined application is better than the single application. The effect of applying boron and molybdenum microelement fertilizer on cowpea quality can be shown in Table 4. (i) Effect on crude protein content. The protein content is an important indicator of the quality of vegetables. The study has found that under the balanced application of N, P, K fertilizer, the combined application of boron and molybdenum microelement fertilizer can increase the crude protein content of cowpea by 4.16 – 19.94%, and there is a highly significant difference in crude protein content between fertilizer treatments and the control. The crude protein content is highest under Treatment B, 19.94% higher than under the control. (ii) Effect on soluble sugar content. The soluble sugar content is an important indicator of plant carbon nutrition and agricultural product traits. The study has found that the soluble sugar content is highest under Treatment B, not significantly different from that under Treatment A, but there is a highly significant difference between Treatment A, and Treatment C, D, E, CK. This indicates that applying boron and molybdenum microelement fertilizer can improve the soluble sugar content of cowpea, and the combined application is better than the single application. (iii) Effect on Vc content. Vc is a reducing agent, and it can improve the body's immunity, resist cancer and aging, and inhibit the formation of nitrite amine. As shown in Table 4, Vc content under various treatments increases compared with the control, with the growth rate of 2.71 – 11.79; Vc content is highest under Treatment B, 11.79% higher than under the control, followed by Treatment A, an increase of 9.71% compared with the control, and there is no significant difference in Vc content between A and B. There is a highly significant difference in Vc content between Treatment B, and Treatment C, D, E, CK. Study results suggest that applying boron and molybdenum microelement fertilizer can increase Vc content of cowpea, and the combined application is better than the single application. (iv) Effect on nitrate content. The nitrate content is a limit indicator of vegetable hygienic quality and also an important factor affecting human health. 81.2% of nitrates absorbed by human are from vegetables, and nitrites are strong carcinogen-nitrosamine precursors, so the research of nitrate content is of important practical significance to the study of cowpea quality. The nitrate content under fertilization treatments is 5 – 15% lower than under the control, and the nitrate content under the combined application is 6 – 9% lower than under the single application. The results show that applying boron or molybdenum microelement fertilizer can reduce the nitrate content of cowpea, and the nitrate content is reduced more significantly under the combined application.

Table 1 Effect of fruit length, fruit weight, amount of seed and thousand kernel weight on cowpea yield increase

Treatment	Fruit length//cm	CK + %	Fruit weight//g	CK + %	Amount of seeds	CK + %	Thousand kernel weight//g	CK + %
A	67.55^{aA}	26.03	24.15^{bB}	13.92	4265.50^{bB}	10.13	153.00^{abAB}	12.09
B	68.55^{aA}	27.89	25.75^{aA}	21.46	4339.00^{aA}	12.03	155.50^{aA}	13.92
C	64.35^{bB}	20.06	23.45^{bcB}	10.61	4142.50^{cC}	6.96	150.00^{bcBC}	9.89
D	63.45^{bB}	18.38	23.05^{cBC}	8.73	4129.00^{cC}	6.61	147.50^{cC}	8.06
E	59.10^{cC}	10.26	21.85^{dCD}	3.07	3943.00^{dD}	1.81	141.50^{dD}	3.66
CK	53.60^{dD}	–	21.20^{dD}	–	3873.00^{eE}	–	136.50^{eE}	–

Table 2 Effect of combined application of boron and molybdenum microelement fertilizer on cowpea yield

Treatment	Pod number	CK + %	Plot yield//kg/ 6m^2	CK + %	Yield per mu//kg/667 m^2	CK + %
A	638.50^{aA}	15.57	17.365^{aA}	15.88	1930.37^{aA}	15.84
B	646.00^{aA}	16.92	17.815^{aAB}	18.89	1980.65^{aA}	18.86
C	606.00^{bB}	9.68	16.535^{bBC}	10.34	1837.69^{bB}	10.28
D	599.50^{bB}	8.51	16.22b^{cC}	8.24	1803.23^{bcC}	8.21
E	577.00^{cC}	4.43	15.75^{cCD}	5.11	1751.085^{cCD}	5.08
CK	552.50^{dD}	–	14.985^{dD}	–	1666.37^{dD}	–

Table 3 N, P, K content increase under various treatments compared with the control

Treatment	N//%	CK + %	P//%	CK + %	K// %	CK + %
A	3.57^{aA}	8.84	0.575^{bA}	11.43	1.715^{aA}	18.48
B	3.62^{aA}	11.28	0.586^{aA}	13.57	1.69^{aA}	16.75
C	3.48^{bB}	6.10	0.541^{cB}	4.84	1.505^{bB}	3.97
D	3.42^{bB}	4.27	0.5515^{cB}	6.88	1.51^{bB}	4.32
E	3.47^{bB}	5.79	0.527^{eC}	2.13	1.4765^{bcBC}	2.00
CK	3.28^{cC}	–	0.516^{fC}	–	1.4475^{cC}	–

Table 4 Effect of combined application of boron and molybdenum microelement fertilizer on cowpea quality

Treatment	Crude protein//g/ kg	CK + %	Soluble sugar//g/ kg	CK + %	Vc//mg/kg	CK + %	Nitrate//mg/kg	CK – %
A	21.10^{aA}	16.90	55.03^{bA}	42.32	325.55^{aA}	9.71	298.5^{eE}	14.74
B	21.65^{aA}	19.94	56.74^{aA}	46.75	331.75^{aA}	11.79	294.6^{fE}	15.85
C	19.10^{bcBC}	5.82	44.11^{cB}	14.08	321.65^{bC}	8.39	326.65^{cC}	6.70
D	19.75^{bB}	9.42	42.135^{dBC}	8.97	319.85^{cC}	7.78	320.15^{dD}	8.53
E	18.80^{cBC}	4.16	40.915^{dCD}	5.82	304.80^{eD}	2.71	331.65^{bB}	5.27
CK	18.05^{dC}	–	38.665^{eD}	–	296.75^{fE}	–	350.10^{aA}	–

4 Conclusions

The combined application of boron and molybdenum fertilizer can promote the growth and development of cowpea plants, and applying appropriate amount of boron and molybdenum microelement fertilizer is beneficial to the normal root growth and organ formation, thereby increasing fruit length, fruit weight, amount of seed and thousand kernel weight, and remarkably improving cowpea yield. Applying boron and molybdenum microelement fertilizer can significantly improve cowpea quality, and the combined application of boron and molybdenum microelement fertilizer is better than the single application of one microelement fertilizer. In terms of the contribution to yield increase, the treatments are in the order of application of boron and molybdenum microelement fertilizer at the seedling and early flowering stages > seed dressing with boron and molybdenum microelement fertilizer > seed dressing with boron fertilizer > seed dressing with molybdenum fertilizer > non-application of boron and molybdenum microelement fertilizer > control. However, the application of microelement fertilizer requires more labor hours and fertilizers, and from economic point of view, Treatment A is feasible.

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ous society in all respects[4]. Shangrao City has developed traffic, rich energy and mineral resources, biological and agricultural and sideline products, natural and cultural tourism resources. It should set foot on such abundant conditions and make constant innovation in science and technology, culture, politics, and management, turn resource advantages and traffic advantages into economic advantages, so as to promote synchronous new industrialization, informationization, urbanization, agricultural modernization, and green development. In the 13th Five-Year Plan period, small town construction should take new industrialization as driving force. Small town construction must take the road of new industrialization, undertake reform of comprehensive poverty alleviation, and finally solve the issues concerning agriculture, farmers and rural areas. Besides, small town construction should take informationization as the link. As an important strategic task of national new urbanization, small town construction itself is a part of new urbanization. Small towns provide path for labor transfer, increase farmers' income, and alleviate man-land conflict. Thus, small town construction is the fundamental path for helping rural poverty-stricken people getting rid of poverty. In addition, it provides a platform for participation of various entities. Small town construction should take agricultural modernization as an opportunity. Main battlefield of small town construction is countryside and main objects are farmers. The key for rural residents getting rid of poverty lies in agricultural modernization. Agricultural modernization is a new road of characteristic agriculture with comprehensive development of farming, forestry, animal husbandry, fishery, and sideline production, as well as deep and multiple level development of agriculture. Finally, small town construction should take green development as guidance. President Xi Jinping always stressed the coordination between economic development and ecological construction, and harmonious development between men and nature. Green development is in essence the overall requirements of other four modernizations. It is an essential indicator for evaluating performance of other four modernizations, and also the core value running through the entire process of small town construction.

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