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Effect of N and K Fertilizers on Yield and Quality of Greenhouse Vegetable Crops*1

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ABSTRACT

The application of large amounts of fertilizers, a conventional practice in northern China for the production of vegetable crops, generally leads to substantial accumulation of soil nutrients within a relatively short period of time. A fixed field experiment was designed to study the effects of nitrogen (N) and potassium (K) fertilizers applied to optimize the yield and quality of typical vegetable crops. Application of N and K fertilizers significantly increased the yields of kidney bean. The largest yields were obtained in the first and second years after application of 1 500 kg N and 300 kg K_2O ha^{-1}. In the third year, however, there was a general decline in yields. Maximum yields occurred when intermediate rates of N and K (750 kg N and 300 kg K_2O ha^{-1}) were applied. However, no significant differences were observed in the concentrations of vitamin C (VC) in kidney bean among different years and various rates of fertilizer treatments. Yields of tomato grown in rotation after kidney bean showed significant responses to the application of N and K in the first year. In the second year, the yields of tomato were much lower. This suggested that the application of N fertilizer did not have any effect upon tomato yield, whereas application of K fertilizer did increase the yield. Application of K fertilizer was often associated with increased sugar concentrations.

Key Words: K fertilizer, N fertilizer, protected cultivation, vegetable quality, vegetable yield

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INTRODUCTION

During the past decade, vegetable production in China has increased at a rate of almost 8% per year (FAO, 2004). According to a survey in 2003, the total cultivated area of almost 8 million ha (excluding melons) accounted for 47% of the vegetable cultivation area worldwide. Almost 4 million ha of this area is in greenhouse cultivation. Shandong is the largest vegetable growing province with more than 2×10^5 ha of greenhouse cultivation (Liu, 2000). The majority of the crops are grown in solar greenhouses with earth or brick walls, plastic sheet coverings, and additional rice straw mats. The major drawback associated with greenhouse vegetable production in China is the over-use of fertilizers. A survey in the suburbs of Beijing revealed that the average rates of application of fertilizers to open field vegetable crops were 780 kg N, 615 kg P_2O_5, and 393 kg K_2O ha^{-1} giving an N:P_2O_5:K_2O ratio of 1.0:0.79:0.50 (Chen *et al.*, 2000). In contrast, a survey conducted in the same year showed that greenhouse vegetables in Shouguang County, Shandong Province, received much higher inputs with the application of 2 388 kg N, 3 274 kg P_2O_5, and 1 216 kg K_2O ha^{-1} per year, a ratio of 1.00 N:1.37 P_2O_5:0.51 K_2O (Liu, 2000). The survey revealed that the rates of application of N and P fertilizers significantly increased the uptake rates by the plants, but that K was usually in short supply. Several studies have been reported on the

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characteristics of soil under protected vegetable growing conditions (Xiao *et al.*, 1999; Zhu *et al.*, 2002; Kaplan *et al.*, 2002; El *et al.*, 2003; Yao *et al.*, 2006), and the effect of potassium application on yields of vegetables and other crops (Majumdar *et al.*, 2000; Sangakkara and Frehner, 2001; Balliu and Ibro, 2002; Chandra *et al.*, 2003; Gent, 2004). There have also been numerous studies on inputs in open field vegetable cropping systems with the application of fertilizers, but little information exists on appropriate fertilizer requirements in protected vegetable cropping conditions. Until now, no detailed studies have been reported that provide a rational basis for recommendations on optimum use of fertilizer to achieve both high yield and quality. The objective of our study was to investigate the effects of different inputs of N and K to determine optimum application rates for two vegetable species typically grown in rotation under greenhouse conditions.

MATERIALS AND METHODS

The experiment was conducted in Xichen Village, Shouguang County, Shandong Province, from January 2000 to January 2002 with a total of five crops in rotation (kidney bean-tomato-kidney bean-tomato-kidney bean). The cultivars used were *Phaseolus vulgaris* 'Lufeng' (kidney bean) and *Lycopersicum esculentum* Mill. 'Maofeng' (tomato). The greenhouse had already been used for vegetable cultivation for 6 years before the field experiment started. The soil is a Typic Haplustalf and selected soil properties are shown in Table I. The cropping system is shown in Table II.

TABLE I

Selected properties of the soil inside the greenhouse

Soil depth	pH	OM	Available N	Available P	Available K	NO_3^--N
cm		%	mg kg^{-1}			
0–20	6.25	1.28	128	256	271	112
20–40	7.27	1.61	62	140	112	56
40–60	7.38	1.34	52	70	108	35
60–80	7.48	1.22	30	28	90	16
80–130	7.49	1.17	28	14	69	21

TABLE II

Cropping system adopted in the experiment

Year	Crop	Transplanting date	Start of harvest	End of harvest
First year	Kidney bean	Jan. 9, 2000	Apr. 4, 2000	Jun. 6, 2000
	Tomato	Aug. 15, 2000	Oct. 17, 2000	Jan. 15, 2001
Second year	Kidney bean	Jan. 30, 2001	Apr. 4, 2001	Jun. 9, 2001
	Tomato	Aug. 20, 2001	Oct. 22, 2001	Jan. 14, 2002
Third year	Kidney bean	Jan. 20, 2002	Mar. 23, 2002	May 30, 2002

The experiment included nine fertilizer treatments in a randomized complete block design with three replicates and a plot size of 16.8 m^2. The nine treatments consisted of the factorial arrangement of all possible combinations of three application rates of N (N0 0, N1 750, and N2 1 500 kg N ha^{-1}) and three rates of K (K0 0, K1 300, and K2 600 kg K_2O ha^{-1}). Each plot received the same amount of P at a rate of 900 kg P_2O_5 ha^{-1}. The fertilizers were applied to each of the five crops.

Nitrogen was applied as a top-dressing in eight split applications, whereas 25% of K was applied as a basal dressing, and the other 75% together with N was applied in eight split top-dressings. Half of the P fertilizer was applied as a basal fertilizer and the remainder was top-dressed in four split applications. Fertilizer materials used were urea (N = 460 g kg^{-1}), triple superphosphate (P_2O_5 = 420 g kg^{-1}), and sulfate of potash (K_2O = 500 g kg^{-1}).

Available soil potassium was extracted with 0.5 mol L^{-1} NH_4OAc (pH = 7.0) and analyzed by flame emission spectrometry. Phosphorus was analyzed by the Olsen method. Soil pH was measured

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