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Response of Cape gooseberry (*Physalis peruviana* L.) to nitrogen application under sandy soil conditions

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Abstract The effect of different nitrogen (N) levels on growth and productivity of Cape gooseberry, cultivated in new reclaimed lands (sandy soil) at Nubaria region in Egypt, was investigated. Nitrogen levels were applied at rates of 50, 100, 150 and 200 kg N ha^{-1} as ammonium sulfate. The amount of N for each treatment was divided into five applications (after transplanting, seven days later, at the beginning of flowering, during fruit set and after the first harvest). Several growth parameters and yield were recorded in addition to nitrogen content in leaves. The results revealed that Cape gooseberry plants responded positively to nitrogen levels in sandy soils. Yield, number of fruits, and diameter of fruits increased significantly by increasing the nitrogen level up to 200 kg N ha^{-1}. Moreover, plant height, number of leaves, N-content in leaves and N-uptake shows a positive reaction to increased nitrogen supply. The quantitative effects of nitrogen on Cape gooseberry plants and the possible explanations of plant responses are discussed.

Keywords Egypt · N · N-content · N-uptake · Plant growth · Yield

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Die Reaktion der Kapstachelbeere (*Physalis peruviana* L.) auf Stickstoffdüngung unter Sandbodenbedingungen

Zusammenfassung Es wurde die Wirkung verschiedener Stickstoffstufen (N) auf Wachstum und Ertrag von Kapstachelbeeren, angebaut in den neuen Landgebieten (Sandböden) bei Nubaria, eine Region in Ägypten, untersucht. Als Stickstoffdüngung wurde Ammoniumsulfat in Stufen von 50, 100, 150 und 200 kg N ha^{-1} verwendet. Die Höhe der gesamt N-Menge wurde zeitlich auf fünf Gaben verteilt (nach dem Pflanzen, sieben Tage später, zu Beginn der Blüte, während der Fruchtbildung, und nach der ersten Ernte). Zusätzlich zu dem Stickstoffgehalt in den Blättern wurden unterschiedliche Wachstumsparameter und der Ertrag der Kapstachelbeeren erfasst. Die Ergebnisse zeigten, dass die Kapstachelbeerpflanzen in sandigen Böden positiv auf Stickstoff reagierten. Bei einer Erhöhung der Stickstoffmenge bis zu einer Stufe von 200 kg N ha^{-1} wurde eine signifikante Steigerung des Ertrags, der Anzahl der Früchte und deren Durchmesser ermittelt. Darüber hinaus zeigten die Pflanzenhöhe, die Anzahl der Blätter, der N-Gehalt der Blätter und die N-Aufnahme eine positive Reaktion auf eine erhöhte Stickstoffversorgung. Die quantitativen Auswirkungen von Stickstoff auf die Kapstachelbeere und die mögliche Erklärungen der pflanzlichen Reaktionen werden diskutiert.

Schlüsselwörter Ägypten · N · N-Gehalt · N-Aufnahme · Pflanzenwachstum · Ertrag

Introduction

Physalis spp. is a group of annuals and perennials, which are grown for their fruits and for decoration and belongs to the family of *Solanaceae*. The berries of some species of *Physalis* are edible, have the size of a cherry tomato and the fruits are produced inside of a papery husk. Therefore, they often are called husk tomatoes. *Physalis peruviana*, commonly known as Cape gooseberry, Poha, goldenberry, ground-cherry etc., is an important vegetable crop because of its high nutritional value, flavor, and potential health benefits. The fruits are eaten fresh or can be prepared as a jam. Sometimes it is canned in heavy sugar syrup. Cape gooseberry is a vegetable fruit showing increased marketing potential in Egypt and becoming promising for exportation.

Nitrogen is an essential element for obtaining high yield fruits. Nitrogen application under sandy soil conditions was studied extensively for other vegetable crops including onion (Mahmoud 2006; Khalil et al. 2007; Khalil 2008; Brar et al. 2008), lettuce (Porto et al. 2008), pepper and tomato (Zhang et al. 2006; Zotarelli et al. 2007), bean (Podsiado et al. 2007), zucchini (Zotarelli et al. 2007), and potato (Alva 2006; Badawy and Ahmed 2006). However, while for tomatoes and other crops there generally exists a lot of information and practical recommendations, the literature sources for husky tomatoes are very limited.

Castro-Brindis et al. (2004) studied the nitrogen demand of *P. ixocarpa* Brot. and found that the highest yield was obtained under high N concentration. Ramos-Lara et al. (2002) conducted experiments to determine the fruit yield and nitrogen use efficiency of *P. ixocarpa* Brot. under drip fertigation in a greenhouse. Four N levels were studied: 0, 80, 160, and 240 kg ha^{-1} and the authors found that maximum fruit yield was obtained with 160 kg N ha^{-1}. These results are not in agreement with the results of Castro-Brindis et al. (2000) who found high correlation between yield and N application studying the effects of different levels of macronutrients during four growth stages of husk tomatoes. Obviously, different experimental conditions and varietal differences may play a role.

Moreover, the soil type and fertility level are very important. Fertile soils, generally recommended for the cultivation of leafy vegetables, could, however, favor vegetative growth over productivity of Cape gooseberry. Chia et al. (1987) indicated that fertile soils may favor vegetative growth over fruit production of Cape gooseberry plants. Accordingly, the response of Cape gooseberry plants to nitrogen application under sandy soils cannot be expected unless different levels of N are being tested.

The aim of this work was to determine the responses of Cape gooseberry (*P. peruviana* L.) grown in new-reclaimed lands (sandy soils) to nitrogen fertilization and to study the quantitative effects of nitrogen levels on plants grown under such conditions.

Materials and methods

Two experiments were carried out for two successive seasons each of years 2006 and 2007 at the experimental station of the National Research Center in Nubaria region in Egypt. Table 1 shows the physical and chemical characteristics of the soil, a sandy soil type.

P. peruviana L. *cv.* “Balady” seeds were sown in the 1st week of March in both years. 35 days after the sowing, the seedlings were transplanted in the field (the distances between hills were 80 cm apart and 1 m between ridges). The plot area covered 8 m^2 and contained ten plants. A drip irrigation system was used for this experiment (4 L h^{-1} discharge rate). The average values of the reference evapotranspiration (mm) in the cultivation region were: 3.4, 4.1, 4.9, 5.7 and 5.8 for the months: March, April, May, June and July respectively. Different nitrogen levels were applied at rates of 50, 100, 150 and 200 kg N ha^{-1} of ammonium sulfate. The amounts of N for each of the treatments were divided into five applications according to the recommendation of the Ministry of Agriculture in Egypt (after transplanting, seven days later, at the beginning of flowering, during fruit set and after the first harvest). Other fertilization and agricultural practices were also applied as recommended by the Ministry of Agriculture, Egypt.

Growth and yield measurements

The following measurements were taken: plant height, number of leaves, number of branches, number of fruits, total yield and fruit diameter.

Chemical measurement

A random sample of 12 plants was taken from each treatment for the determination of nitrogen content. Nitrogen contents of leaves were measured according to FAO (1980). In addition, the total nitrogen per plants (g N plant^{-1}) was calculated.

Statistics

The design of the experiments was established as a complete randomized block design with four replicates. Analysis of variance was carried out according to Snedecor and Cochran (1967). Least significant difference (L.S.D.) at 5% was used to compare between means. Data were subjected to regression analysis under the different nitrogen levels for each of the characters measured.

Table 1 Physical and chemical properties of the experimental soil

Physical properties						
Clay	Silt	Texture	F.C. %	W.P. %		
9.26	0.66	Sandy	16.57	5.25		
Chemical analysis						
pH	Ca	Mg	Na	K	HCO_3	Cl
	Meq./L.					
8.2	7.02	0.527	0.982	0.31	1.3	0.566

Results and Discussion

Effects of nitrogen levels on growth and productivity

Cape gooseberry plants responded positively to increasing the nitrogen levels as shown in Tables 2 and 3. Plant height, number of leaves, number of branches and fresh weight of plants significantly increased by increasing the nitrogen levels in both years.

Nowadays, one of the major challenges of agriculture is to manage water and nutrients in order to maximize production and improve the product quality, while minimizing the adverse environmental effects. Water is becoming a limiting factor in many arid lands in the world and the amount and time of irrigation should be scheduled to maximize the yield and to minimize water application (El-Tohamy et al. 1999). Nitrogen is also a limiting factor which markedly affects plant growth and productivity as well, especially under sandy soil conditions. However, monitoring soil and plant nutrient status is an essential safeguard to ensure maximum crop productivity. High dosage of fertilizers could, in analogy to fertile soils, result in favoring vegetative growth over fruit production and this in turn can reduce the total yield of plants. In the present study, the results showed that Cape gooseberry plants responded positively to increasing the nitrogen levels under sandy soil conditions of Nubaria region, as shown in Tables 2 and 3. The level of 200 kg ha^{-1} obtained the highest fruit productivity.

Moreover, the differences between treatments in number of fruits, and fruit diameter were also significant, indicating that increasing the nitrogen level under sandy soil conditions is essential for obtaining high growth and yield of Cape gooseberry plants. The vigorous growth of Cape gooseberry plants required high nitrogen application especially under soils with poor fertility such as sandy soils. These results are in accordance with the results of Castro-Brindis et al. (2004) and in discordance with the results of Ramos-Lara et al. (2002). The authors of the last paper found that the maximum fruit yield was obtained with 160 kg N ha^{-1}.

Table 2 Effects of nitrogen levels on some vegetative growth parameters

Treatment Application of ammonium sulfate at	Plant height (cm)	Number of branches	Plant fresh weight (g $plant^{-1}$)
	1st year		
50 kg N ha^{-1}	65.00 d	11.75 d	274.25 d
100 kg N ha^{-1}	70.75 c	13.25 c	326.25 c
150 kg N ha^{-1}	74.75 b	14.75 b	655.75 b
200 kg N ha^{-1}	88.25 a	16.25 a	846.25 a
L.S.D. at 5%	1.27	0.77	3.35
	2nd year		
50 kg N ha^{-1}	58.61 d	10.89 d	252.81 d
100 kg N ha^{-1}	63.98 c	12.25 c	299.44 c
150 kg N ha^{-1}	67.71 b	13.48 b	602.68 b
200 kg N ha^{-1}	80.31 a	15.14 a	778.93 a
L.S.D. at 5%	1.54	0.76	3.15

Means followed by the same letter(s) within each column are not significantly different at.

Table 3 Effects of nitrogen levels on number of fruits, total yield, and fruit diameter

Treatment Application of ammonium sulfate at	Number of fruits (per plant)	Total yield (g $plant^{-1}$)	Fruit diameter (cm)
	1st year		
50 kg N ha^{-1}	74.18 d	159.19 d	1.50 c
100 kg N ha^{-1}	80.50 c	282.71 c	1.63 b
150 kg N ha^{-1}	123.05 b	394.88 b	1.73 ab
200 kg N ha^{-1}	164.45 a	472.50 a	1.80 a
L.S.D. at 5%	3.027	15.090	0.121
	2nd year		
50 kg N ha^{-1}	68.62 d	147.36 d	1.40 c
100 kg N ha^{-1}	74.40 c	263.31 c	1.54 b
150 kg N ha^{-1}	113.53 b	367.46 b	1.64 ab
200 kg N ha^{-1}	152.44 a	438.12 a	1.71 a
L.S.D. at 5%	2.480	14.240	0.104

Means followed by the same letter(s) within each column are not significantly different at.

For tomato plants, Guertal and Kemble (1998) found that yield was increased by N application regardless of the sources of N used in their experiments. Crene (1990) examined different levels of N (75, 125 or 175 kg ha^{-1}) on growth and yield of tomato plants and found that the highest yields were obtained with 175 kg N, in either form of N (ammonium sulfate or calcium ammonium nitrate). Brar et al. (2008) studied the effects of different levels of N on growth and productivity of onion plants and found that the plants responded significantly to up to 125 kg nitrogen ha^{-1}. In another investigation on onion plants, Mahmoud (2006) found that the application of N fertilizer significantly increased plant height and fresh and dry bulb weights, total yield and average weight of ten bulbs.

Moreover, Podsiado et al. (2007) investigated the effects of drip irrigation and mineral fertilization of N and other minerals on the yield of bean plants under sandy soil conditions and found that the yield of bean plants increased because of irrigation and mineral fertilizer application by 6 and 40% respectively. In a study carried out by Zotarelli et al. (2007) on the effects of N application on other vegetable crops including zucchini, pepper and tomato, they stated that proper N fertilizer and irrigation management can reduce nitrate leaching while maintaining crop yield and this is critical to enhance the sustainability of vegetable production on soils with poor water and nutrient-holding capacity.

N-uptake by plants

According to Mmolawa and Or (2000) soil properties, crop characteristics and growing conditions affect the nutrient uptake. Mahmoud (2006) found that increasing N levels resulted in a significant increase in N, P and K contents and uptakes by onion plants. Moreover, Badawy and Ahmed (2006) indicate that N, P and K concentrations in potato leaves were significantly affected by increasing N, P and K rates under sandy soil conditions. Rising N-application rates caused a significant increase in N-content and N-uptake of plants of the present paper (Table 4). It was shown that *P. peruviana* had the lowest N-uptake in the lowest nitrogen level. The quantity of N-uptake per plant increased with the increasing of N-supply. The highest N-uptake was obtained by 200 kg ha^{-1}. The differences in N-uptake between the treatments were stronger than the differences in N-content in dry weight due to the yield differences. This is in agreement with results of Porto et al. (2008). The authors investigated the effects of five doses of N (30, 60, 90, 120 and 150 kg ha^{-1}) on lettuce plants grown under sandy soil and found that nitrate content in roots, stems and leaves increased linearly with nitrogen application.

Table 4 N-contents (%) of leaves and N-uptake (g $plant^{-1}$) of *P. peruviana* at the end of experiment

Treatment Application of ammonium sulfate at	Nitrogen content in leaves (%)	N-uptake (g $plant^{-1}$)
	1st year	
50 kg N ha^{-1}	3.62 d	2.77 d
100 kg N ha^{-1}	3.80 c	5.58 c
150 kg N ha^{-1}	3.96 b	8.56 b
200 kg N ha^{-1}	4.19 a	10.63 a
L.S.D. at 5%	0.115	0.107
	2nd year	
50 kg N ha^{-1}	3.93 d	3.17 d
100 kg N ha^{-1}	4.17 c	5.91 c
150 kg N ha^{-1}	4.45 b	9.14 b
200 kg N ha^{-1}	4.85 a	12.32 a
L.S.D. at 5%	0.056	0.155

Means followed by the same letter(s) within each column are not significantly different at.

Quantitative effects of nitrogen levels on growth and yield of Cape gooseberry

The results presented in Tables 2, 3 and 4 indicate that there are linear relationships between increasing the nitrogen levels and improving growth characters (plant height, number of leaves, number of branches and fresh weight of plants), yield (number of fruits and total yield), and fruit diameter.

Although these results indicate that increasing the nitrogen level more than 200 kg N ha^{-1} will probably have a positive effect on plant parameters and yield of *P. peruviana*, the response of Cape gooseberry may not follow this trend. Fertilization is difficult to be managed for plants such as Cape gooseberry: overdose of nitrogen can sometimes cause Cape gooseberry plants to develop large vegetative growth at the expense of fruit production and in this case, low yield and quality are expected. Ramos-Lara et al. (2002) indicated that the maximum fruit yield was obtained with 160 kg N ha^{-1}. These results are not in agreement with our results, probably as a consequence of different soil types.

Sandy soils have, on one hand, the advantage of ease of tillage and they allow timely production operations such as planting and harvesting. Sandy soils, however, have the disadvantage that mobile nutrients such as nitrogen can be leached by heavy rain or over irrigation (Simonne and Hochmuth 2005), due to inherent constraints like low CEC, rapid hydraulic conductivity, and faster infiltration rate. The plants grown under such conditions often suffer from low nutrients and the deficiency of N is considered as a major production constraint in this soil type. This means that the cultivated crop in this soil requires large quantity of nutrients to support its growth and yield. Nutrients such as nitrate are mobile and if there is sufficient water in the soil, it can move quickly through the soil profile. Therefore, according to Simonne and Hochmuth (2005), sandy soils must be managed carefully with regard to fertility programs. The high leaching risk of nitrogen in sandy soils has to be controlled. In addition, careful application of water should be able to avoid moving of such nutrients below the root zone (Drost and Koenig 2001; Rajput and Patel 2006).

The present study indicated that under sandy soil conditions in Nubaria region, increasing the nitrogen levels up to 200 kg N ha^{-1} was important to improve growth and yield of Cape gooseberry. The results also revealed that the plants still can balance between vegetative growth and yield at this level. However, adverse effects on productivity when increasing N level more than 200 kg N ha^{-1} can be expected as e.g. Ramos-Lara. et al. (2002) reported. In order to improve the N management, the time of N application and the combination with different irrigation systems need to be tested in sandy soil conditions. With respect to the irrigation, probably systems such as drip irrigation would improve the management of N supply as well. Furthermore, investigations concerning the product quality will be interesting.

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