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Effect of N Fertilization on Pod and Seed Characteristics of Okra in Relation to Plant Part

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Abstract

Four cultivars of okra (*Abelmoschus esculentus* [L.] Moench. cv. 'Boyiatiou', 'Veloudo', 'Pylaias' and 'Clemson') were sown on 1st of May (Experiment 1) and 20th of May, 2011 (Experiment 2) and fertilized with three nitrogen levels (150, 300 and 450 mg N l^{-1}). The pods were harvested from three plant parts (upper, middle and lower part) and the seeds were extracted from the pods either immediately after harvest or after storage for 15 days at room temperature. The present study provides new information on the seed quality of four cultivars of okra in relation to N level and the region (upper, lower and middle) of the plant from which harvest took place. N application generally increased flowering, but pod set increased only in 'Boyiatiou'. Pod dimensions (length and diameter) were largely unaffected by N level, irrespective of the position of the pods on the plant, as was the 100-seed weight and seed germination. The slight (insignificant) increase in seed germination of 'Boyiatiou' in response to N is worthy of further study in view of the susceptibility of this cultivar to seed hardness. There was no benefit of pod after-ripening, but seed storage for 18 months at room temperature proved to be a positive way to improve seed quality, especially in 'Boyiatiou'.

Keywords: *Abelmoschus esculentus* L., nitrogen fertilization, okra, seed hardness, seed quality

1. Introduction

Although several studies of the nutrient requirements of okra (*Abelmoschus esculentus* [L.] Moench.) have been carried out, these have been concerned primarily with the fresh crop and almost entirely refer to large-fruiting cultivars, such as 'Clemson spineless' (Asif & Greig, 1972; Shrestha, 1983; Olasantan, 1994; Lamont, 1999). In Greece and Turkey, however, there is a market preference for small-fruiting cultivars (Duzyaman & Vural, 2009; Koutsos, 2009) for which few data are available about their nutritional requirements and virtually none for the seed crop (Passam & Rekoumi, 2009; Rekoumi, Karapanos, Akoumianakis, & Passam, 2012).

Nitrogen is reported to promote the vegetative growth of plants and increase assimilation by making available more photosynthetic area (Chaurasia & Singh, 1999; Bangar, Parmar, & Maini, 2000). Olasantan (1999) reported that the growth and yield attributes of okra increased with increasing rates of N. The increase, however, was proportionally greater for growth attributes than for yield characters, and when considering a seed crop, seed quality expressed in terms of 100-seed weight, viability percentage and vigour did not show significant differences due to N application (Singh, Gulshan, & Jain, 1999).

Other factors affecting seed production and quality in okra include the sowing time (Yadav, Dhankar, Deshwal, & Tomer, 2001), the prevailing environmental conditions (Anjum & Amjad, 1999; Yadav & Dhankhar, 1999;

Amjad, Anjum, & Hussain, 2001) and genetic and soil factors (Majanbu, Ogunlela, Ahmed, & Olarewaju, 1985).

Fruit position on the plant has also been reported to influence seed quality in okra. For example, germination varied from 28-58% in upper pods, 29-87% in middle pods, and 67-83% in lower pods in different cultivars of okra (Bhatt & Srinivasa Rao, 1998). Malik, Singh, Nehra, Khurana, Dahiya, and Singh (2000) also found that the seeds obtained from the pods of the lower and middle nodes had higher germination rates than those from the upper nodes. Seed quality may relate to the moisture content and the rate of seed drying, where low final moisture content and rapid drying promote the formation of hard seeds and reduce the total percent of seed germination (Demir, 2001; El-Balla, Saidahmed, & Makkawi, 2011). Cabrera, Baskin, and Nsapato (1995) observed that no hard seeds were detected until seeds reached physiological maturity, while El-Balla et al. (2011) reported that okra seeds with 13% moisture content tended to show little or no seed hardness, but once the moisture content dropped to 4-6% seed hardness became prevalent. Seed hardness varies among different okra cultivars (Bennett, 1959) and is particularly high in the Greek cv. 'Boyiatiou' (Passam & Rekoumi, 2009). It is also affected by the level of N application during cultivation (Rekoumi, Moustakas, Passam & Akoumianakis, 2013).

It is possible that the rate of seed drying relates to the position of the pod on the mother plant. In view of the significance of N and the rate of seed drying on seed quality (especially seed hardness) two experiments were undertaken as described in this study.

2. Material and Methods

2.1 Experimental Conditions

The experiments of the present study were carried out at the Experimental Farm of the University of Thessaly, Greece during the growing season of 2011. Plants were cultivated in soil, the composition of which was 48% Sand, 29% Silt, 23% Clay and 1.3% Organic matter with pH 7.9.

2.2 Plant Material, Treatments and Data Collection

Seeds of four okra cultivars (e.g. 'Boyatiou', 'Veloudo', 'Pylaias' and 'Clemson') were sown in seed trays on 1st and 20th of May, 2011 (Experiments 1 and 2, respectively) and kept under controlled temperature (20 °C) until field transplantation. Plants were transplanted after 20 days in both experiments, when the plants had 3-4 true leaves, and placed in rows with 1 m between each row and 30 cm between plants within the rows. The plants were irrigated regularly on a weekly basis via a drip irrigation system. Fertilizers were applied manually at regular intervals (once a week) at a dose of 0.5 L per plant. P and K, each were applied at a constant concentration of 150 mg L^{-1}, while N was applied at three levels i.e. 150 mg L^{-1} (F_1 or control), 300 mg L^{-1} (F_2) and 450 mg L^{-1} (F_3). Side shoots were not removed and the total flower induction per plant and the number of pods set per plant (i.e. on the main stem and side shoots) were recorded.

The pods were harvested from three parts on the same plants, i.e. upper, middle and lower plant part, which were defined according to the cultivar and the total number of pods set (e.g. from 2-3 pods for each plant part for cv. 'Boyatiou' to 7-8 pods for cv. 'Clemson'). For each part, 5 pods were randomly selected from a batch sample at each harvest and the pod dimensions (length of pod – including beak, but not the peduncle- and diameter), average number of seeds per pod and 100-seed weight recorded. After harvesting the pods, seeds were either dried within the pods for 15 days (pod drying method) or after immediate extraction from the pods (seed drying method). Both methods were applied at room temperature (about 25 °C). Also in the pod drying method, the seed moisture content was determined prior to and after drying according to standard methods (ISTA, 2009).

Seed germination tests were conducted using 100 seeds per treatment, with four replications (400 seeds in total). The germination tests were carried out on seeds after extraction from the pods either immediately after harvest or after drying within pods for 15 days at room temperature. Just prior to the germination tests, seeds were surface sterilized firstly with Chlorine Dioxide, 1 to 20 parts deionized water for 10 sec. and then with Mancozeb fungicide (80% w/w diluted in distilled water at a concentration of 2 g per liter) and placed in sterilized Petri dishes on a double layer of Whatman No. 1 filter paper moistened with distilled water. The Petri dishes were placed in the dark in an incubator at 25 °C for 21 days and every 2 days germinated seeds were counted and removed and, in the case of moisture deficiency, distilled water was added. Seeds were considered germinated when the tip of the radical had grown free of the seed coat (Wiese & Binning, 1987; Auld, Bettis, Crock, & Kephart, 1988). Those seeds which did not germinate (not hydrated) and remained rigid after the time period of 21 days in the incubator were considered to be hard seeds, but without testing by scarification (Passam & Polyzou, 1997) or another means, e.g. tetrazolium (Moore, 1985). Germination percentage was calculated by the following formula (ISTA, 2009).

$$Germination\ (\%) = \frac{Number\ of\ seeds\ germinated}{Number\ of\ seeds\ tested} \times 100$$

Seeds were also stored at room temperature for a period of 18 months and tested for their germination potential at the end of storage.

2.3 Statistical Analysis

The experiment was laid out in a Randomized Complete Block design with factorial arrangements using three replications (3 × 12 = 36 plots and 10 plants in each plot). Statistical analysis was carried out by using SAS statistical package software (SAS Institute Inc., USA) and the means were compared by employing least significant difference (LSD) test at $p < 0.05$. Graphs were generated by using Microsoft Office Excel software (Microsoft Corporation, USA).

3. Results

3.1 Harvesting and Climatic Conditions

The climatic conditions of the experimental site are given in Figure 1. The temperature gradually increased from May to July and then decreased till October. There was a difference of about 12-16 °C between minimum and maximum temperatures (in mean overall differences) throughout the experimental period. There was no rainfall during July, but during the other months varied from 23 to 43 mm; relative humidity thus decreased during July, but afterwards increased progressively. This means that as the number of days from anthesis increased (from 30-50 DAA) pods were increasingly exposed to lower temperatures and higher humidity.

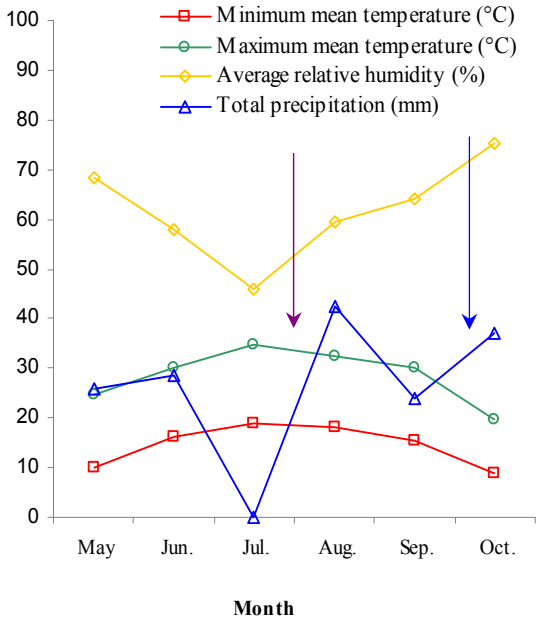

Figure 1. Climate conditions of the experimental site during the cultivation period 2011 (vertical arrows indicate the start and finish point of pod harvest)

3.2 Total Flower Induction

In both experiments, flower induction was significantly affected by the N level in all the cultivars studied, except cv. 'Pylaias' (Table 1). At all the N levels, 'Clemson' produced a higher number of flowers per plant than the other cultivars. Except in 'Boyiatiou', the flower induction of which was very low at 300 ppm N, in both experiments the best N rates were 150 and 300 ppm N. Between cultivars, 'Boyiatiou' produced the lowest number of flowers at all N levels, whereas 'Clemson' produced the highest number of flowers (Figure 2).

Table 1. Effect of N levels on flower induction and pod set of four okra cultivars

Cultivar (C)	N level (mg l^{-1}) (F)	Total flower induction (flowers/plant)		Pod set (pods/plant)	
		Experiment 1 (1st of May)	Experiment 2 (20th of May)	Experiment 1 (1st of May)	Experiment 2 (20th of May)
	150 (F_1)	14.8[a]	13.0[a]	5.5[b]	4.8[b]
'Boyiatiou'	300 (F_2)	8.6[b]	7.0[b]	5.0[b]	4.2[b]
	450 (F_3)	13.4[a]	11.8[a]	11.5[a]	10.0[a]
Mean		*12.2*	*10.6*	*7.3*	*6.3*
LSD		***2.6***	***2.7***	***2.5***	***2.4***
	150 (F_1)	20.5[ab]	18.9[ab]	18.4[ab]	15.0[a]
'Veloudo'	300 (F_2)	22.9[a]	21.0[a]	20.9[a]	16.9[a]
	450 (F_3)	17.8[b]	16.0[b]	16.8[b]	13.8[a]
Mean		*20.4*	*18.6*	*18.7*	*15.2*
LSD		***4.3***	***4.4***	***2.7***	***3.4***
	150 (F_1)	23.9[a]	21.0[a]	22.6[a]	19.9[a]
'Pylaias'	300 (F_2)	23.3[a]	21.0[a]	21.9[a]	17.9[a]
	450 (F_3)	18.9[a]	16.4[a]	18.0[a]	14.9[a]
Mean		*22.0*	*19.4*	*20.8*	*17.5*
LSD		***7.5***	***7.6***	***4.7***	***6.2***
	150 (F_1)	26.8[a]	24.8[a]	24.8[ab]	21.6[b]
'Clemson'	300 (F_2)	29.6[a]	26.9[a]	28.0[a]	23.7[a]
	450 (F_3)	20.5[b]	18.7[b]	20.3[b]	18.5[b]
Mean		*25.6*	*23.4*	*24.3*	*21.2*
LSD		***6.0***	***5.9***	***3.9***	***5.1***
C x F					
(C x F_1)		*	*	*	*
(C x F_2)		*	*	*	*
(C x F_3)		*	*	*	*

Mean separation by LSD test. Mean values in the same column for each cultivar separately followed by different letters differ significantly at $p = 0.05$. * = statistically significant ($p < 0.05$).

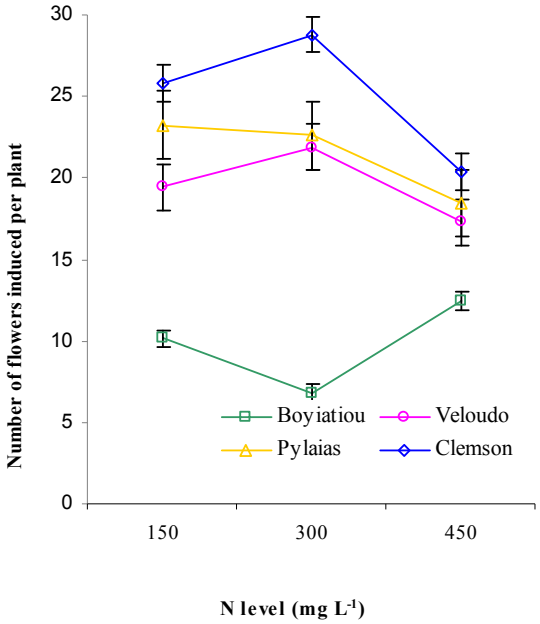

Figure 2. Effect of N levels on the total flower induction of four okra cultivars

3.3 Pod Set

In both experiments, the N level had a significant effect on pod set in all the cultivars except 'Pylaias' (both experiments) and 'Veloudo' (Experiment 2, only). In 'Boyiatiou' pod set was highest at 450 ppm N, whereas in the other cultivars pod set was reduced at this N concentration, although not always to a statistically significant extent (Table 1). No differences in pod set were detected between N levels of 150 and 300 ppm in any of the cultivars, except 'Clemson' where, in Experiment 2, pod set was higher at 300 ppm N than at 150 ppm N (Table 1, Figure 3).

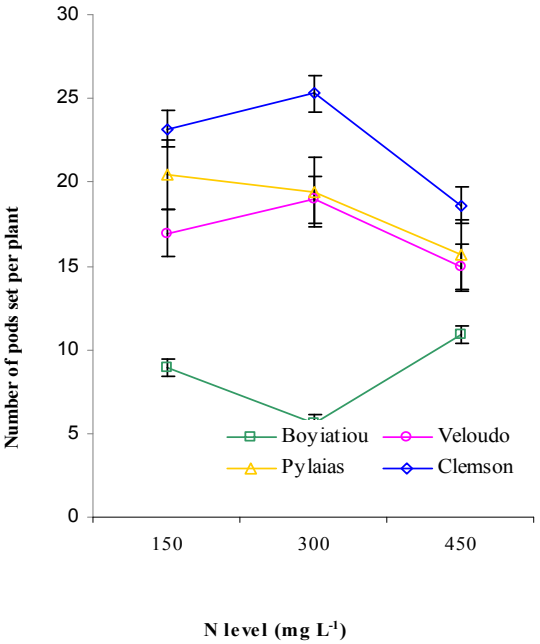

Figure 3. Effect of N levels on the number of pods of four okra cultivars

3.4 Pod Length

Overall, in Experiment 1 pod length was significantly higher for pods harvested from the middle region of the plant than those at the lower or higher regions (Table 2), whereas in Experiment 2 the same trend was observed (except in 'Boyiatiou'), but to a non-significant degree (Table 3). In Experiment 1, with few exceptions (Pylaias in the middle region and Clemson in both the middle and lower regions) there was virtually no effect of N on pod length, irrespective of the position of the pods on the plant. Similarly in Experiment 2, N level did not affect pod length in the majority of cases, irrespective of cultivar and pod position on the plant.

Table 2. Effect of N levels on the length and diameter of pods harvested from different plant parts of four okra cultivars (Experiment 1)

Cultivar (C)	N level (mg l^{-1}) (F)	Pod length (cm)			LSD	Pod diameter (cm)			LSD
		Upper	Middle	Lower		Upper	Middle	Lower	
	150 (F_1)	$17.8^{a(b)}$	$18.9^{a(a)}$	$15.2^{a(c)}$	**1.4**	$2.2^{a(a)}$	$2.3^{a(a)}$	$2.0^{a(a)}$	**0.4**
'Boyiatiou'	300 (F_2)	$17.2^{ab(ab)}$	$18.8^{a(a)}$	$16.3^{a(b)}$	**1.9**	$2.1^{ab(a)}$	$2.3^{a(a)}$	$2.2^{a(a)}$	**0.2**
	450 (F_3)	$16.2^{b(b)}$	$19.3^{a(a)}$	$16.6^{a(b)}$	**1.9**	$1.9^{b(b)}$	$2.3^{a(a)}$	$2.2^{a(a)}$	**0.1**
Mean		*17.0*	*19.0*	*16.0*		*2.0*	*2.3*	*2.1*	
LSD		***1.4***	***0.8***	***2.6***		***0.2***	***0.2***	***0.3***	
	150 (F_1)	$20.1^{a(b)}$	$24.1^{a(a)}$	$20.8^{a(b)}$	**1.4**	$2.0^{a(b)}$	$2.2^{a(ab)}$	$2.3^{a(a)}$	**0.2**
'Veloudo'	300 (F_2)	$19.9^{a(c)}$	$24.5^{a(a)}$	$21.5^{a(b)}$	**0.6**	$2.0^{a(a)}$	$2.4^{a(a)}$	$2.3^{a(a)}$	**3.5**
	450 (F_3)	$21.0^{a(b)}$	$23.9^{a(a)}$	$20.5^{a(b)}$	**1.4**	$2.0^{a(b)}$	$2.3^{a(a)}$	$2.2^{a(ab)}$	**0.2**
Mean		*20.3*	*24.1*	*20.9*		*2.0*	*2.3*	*2.2*	
LSD		***1.2***	***0.9***	***1.4***		***0.2***	***0.2***	***0.3***	
	150 (F_1)	$17.9^{a(b)}$	$20.7^{a(a)}$	$18.1^{a(b)}$	**1.6**	$2.0^{a(a)}$	$1.8^{a(b)}$	$1.9^{ab(ab)}$	**0.1**
'Pylaias'	300 (F_2)	$19.9^{a(a)}$	$19.2^{b(a)}$	$18.2^{a(a)}$	**2.6**	$1.9^{b(a)}$	$1.6^{a(b)}$	$1.8^{b(ab)}$	**0.2**
	450 (F_3)	$18.2^{a(ab)}$	$19.2^{b(a)}$	$17.5^{a(b)}$	**1.4**	$2.1^{a(a)}$	$1.7^{a(b)}$	$2.0^{a(a)}$	**0.2**
Mean		*18.6*	*19.7*	*17.9*		*2.0*	*1.7*	*1.9*	
LSD		***2.5***	***0.6***	***2.2***		***0.2***	***0.2***	***0.1***	
	150 (F_1)	$15.6^{a(ab)}$	$15.3^{b(b)}$	$15.9^{ab(a)}$	**0.4**	$1.6^{a(b)}$	$1.6^{a(b)}$	$1.8^{a(a)}$	**0.1**
'Clemson'	300 (F_2)	$14.9^{a(b)}$	$17.0^{a(a)}$	$14.5^{b(b)}$	**1.3**	$1.6^{a(a)}$	$1.6^{a(a)}$	$1.8^{a(a)}$	**0.3**
	450 (F_3)	$15.6^{a(a)}$	$16.9^{a(a)}$	$16.4^{a(a)}$	**1.7**	$1.7^{a(a)}$	$1.7^{a(a)}$	$1.9^{a(a)}$	**0.3**
Mean		*15.3*	*16.4*	*15.6*		*1.6*	*1.6*	*1.8*	
LSD		***0.9***	***1.0***	***1.7***		***0.2***	***0.2***	***0.1***	
C x F									
(C x F_1)		*	*	*		*	*	*	
(C x F_2)		*	*	*		*	*	*	
(C x F_3)		*	*	*		*	*	*	

Mean separation by LSD test. Mean values in the same column for each cultivar separately followed by different letters differ significantly at $p = 0.05$. Means in each row for each pod characteristic separately followed by the same letter in parenthesis do not differ significantly at $p = 0.05$.

- = statistically significant ($p < 0.05$).

Table 3. Effect of N levels on the length and diameter of pods harvested from different plant parts of four okra cultivars (Experiment 2)

Cultivar (C)	N level (mg l^{-1}) (F)	Pod length (cm)			LSD	Pod diameter (cm)			LSD
		Upper	Middle	Lower		Upper	Middle	Lower	
	150 (F_1)	$17.4^{b(b)}$	$17.8^{a(ab)}$	$18.6^{a(a)}$	**0.9**	$2.1^{a(a)}$	$2.2^{a(a)}$	$2.1^{a(a)}$	**0.2**
'Boyiatiou'	300 (F_2)	$19.9^{a(a)}$	$17.5^{a(b)}$	$16.6^{b(b)}$	**1.6**	$2.3^{a(a)}$	$2.1^{a(a)}$	$2.1^{a(a)}$	**0.2**
	450 (F_3)	$19.2^{ab(a)}$	$18.4^{a(a)}$	$18.2^{a(a)}$	**1.4**	$2.2^{a(ab)}$	$2.3^{a(a)}$	$2.0^{a(b)}$	**0.2**
Mean		*18.8*	*17.9*	*17.8*		*2.2*	*2.2*	*2.0*	
LSD		***2.0***	***0.9***	***0.8***		***0.2***	***0.2***	***0.2***	
	150 (F_1)	$18.7^{a(c)}$	$24.0^{a(a)}$	$21.9^{ab(b)}$	**2.0**	$1.7^{a(b)}$	$2.4^{a(a)}$	$2.2^{a(a)}$	**0.3**
'Veloudo'	300 (F_2)	$20.8^{a(b)}$	$21.7^{b(ab)}$	$23.4^{a(a)}$	**2.5**	$2.2^{a(a)}$	$2.2^{b(a)}$	$2.3^{a(a)}$	**0.3**
	450 (F_3)	$19.8^{a(b)}$	$22.9^{ab(a)}$	$20.9^{b(ab)}$	**2.1**	$2.0^{a(b)}$	$2.4^{a(a)}$	$2.3^{a(ab)}$	**0.3**
Mean		*19.7*	*22.8*	*22.0*		*1.9*	*2.3*	*2.2*	
LSD		***2.1***	***2.2***	***2.4***		***0.3***	***0.1***	***0.4***	
	150 (F_1)	$18.9^{a(ab)}$	$20.4^{ab(a)}$	$17.1^{b(b)}$	**2.2**	$1.8^{a(ab)}$	$2.0^{ab(a)}$	$1.7^{a(b)}$	**0.2**
'Pylaias'	300 (F_2)	$19.5^{a(b)}$	$21.4^{a(a)}$	$19.7^{a(b)}$	**1.6**	$2.1^{a(a)}$	$2.1^{a(a)}$	$1.7^{a(b)}$	**0.3**
	450 (F_3)	$19.7^{a(a)}$	$18.5^{b(ab)}$	$17.2^{b(b)}$	**1.3**	$1.9^{a(a)}$	$1.8^{b(ab)}$	$1.6^{a(b)}$	**0.2**
Mean		*19.3*	*20.1*	*18.0*		*1.9*	*1.9*	*1.6*	
LSD		***2.0***	***1.3***	***1.9***		***0.3***	***0.2***	***0.2***	
	150 (F_1)	$16.0^{b(a)}$	$16.9^{a(a)}$	$16.2^{b(a)}$	**0.8**	$1.6^{b(a)}$	$1.5^{a(ab)}$	$1.4^{a(b)}$	**0.1**
'Clemson'	300 (F_2)	$16.5^{b(a)}$	$17.0^{a(a)}$	$17.3^{a(a)}$	**0.8**	$1.5^{b(a)}$	$1.5^{a(a)}$	$1.5^{a(a)}$	**0.1**
	450 (F_3)	$19.2^{a(a)}$	$16.9^{a(b)}$	$17.5^{a(ab)}$	**2.1**	$1.9^{a(a)}$	$1.4^{a(b)}$	$1.6^{a(ab)}$	**0.3**
Mean		*17.2*	*16.9*	*17.0*		*1.6*	*1.4*	*1.5*	
LSD		***2.1***	***0.8***	***0.9***		***0.2***	***0.1***	***0.2***	
C x F									
(C x F_1)		*	*	*		*	*	*	
(C x F_2)		*	*	*		*	*	*	
(C x F_3)		ns	*	*		ns	*	*	

Mean separation by LSD test. Mean values in the same column for each cultivar separately followed by different letters differ significantly at $p = 0.05$. Means in each row for each pod characteristic separately followed by the same letter in parenthesis do not differ significantly at $p = 0.05$.

* = statistically significant ($p < 0.05$).

3.5 Pod Diameter

Pod diameter was not significantly affected by the pod position on plant in either experiment and overall ranged from 1.6-2.3 cm (Experiment 1) and 1.4-2.3 cm (Experiment 2) (Tables 2-3). In addition, with few exceptions (e.g. middle pods of Veloudo and upper pods of Clemson in Experiment 2) pod diameter was not significantly affected by the N levels (Tables 2-3).

Overall, in both experiments the pod diameter of cv. 'Clemson, was lower than that of the other cultivars, irrespective of N level and the position of the pods on the plant.

3.6 Number of Seeds per Pod

The number of seeds per pod was higher in the pods from the middle and upper part of the plant in 'Clemson' and 'Pylaias', as well as in 'Boyiatiou'(at 450 ppm N) and 'Veloudo' (at 150 ppm N) in Experiment 1 (Table 4), but only in 'Veloudo' (350 and 450 ppm N) in Experiment 2 (Table 5).

The N level had no significant effect on the number of seeds per pod in any cultivar in either experiment, except 'Veloudo' where seed number was lower at 150 ppm N than 450 ppm N in the lower pods (Experiment 1) and upper pods (Experiment 2), but higher in 'Pylaias' (middle pods) and 'Clemson' (lower pods) in Experiment 1 and in 'Veloudo' (middle pods) in Experiment 2.

Table 4. Effect of N levels on seed characteristics from pods harvested from different plant parts of four okra cultivars (Experiment 1)

Cultivar (C)	N level (mg l^{-1}) (F)	Number of seeds/pod			LSD	100-seed weight (g)			LSD
		Upper	Middle	Lower		Upper	Middle	Lower	
	150 (F_1)	$72.7^{a(a)}$	$64.4^{a(b)}$	$67.4^{a(ab)}$	**6.9**	$28.9^{a(a)}$	$26.2^{a(a)}$	$28.2^{a(a)}$	**7.3**
'Boyiatiou'	300 (F_2)	$68.2^{a(a)}$	$63.2^{a(a)}$	$68.4^{a(a)}$	**8.8**	$25.1^{a(a)}$	$28.1^{a(a)}$	$24.7^{a(a)}$	**6.4**
	450 (F_3)	$73.2^{a(a)}$	$68.3^{a(ab)}$	$62.7^{a(b)}$	**5.7**	$26.5^{a(a)}$	$26.8^{a(a)}$	$29.4^{a(a)}$	**7.9**
Mean		*71.3*	*65.3*	*66.1*		*26.8*	*27.0*	*27.4*	
LSD		***19.4***	***8.1***	***6.6***		***10.4***	***10.7***	***11.7***	
	150 (F_1)	$71.5^{a(a)}$	$57.9^{a(b)}$	$48.0^{b(b)}$	**10.1**	$34.5^{a(a)}$	$35.9^{a(a)}$	$34.4^{a(a)}$	**8.2**
'Veloudo'	300 (F_2)	$62.8^{a(a)}$	$56.3^{a(a)}$	$59.8^{a(a)}$	**14.6**	$35.3^{a(a)}$	$35.7^{a(a)}$	$31.2^{a(a)}$	**8.1**
	450 (F_3)	$70.7^{a(a)}$	$60.8^{a(a)}$	$61.4^{a(a)}$	**11.2**	$34.0^{a(a)}$	$34.6^{a(a)}$	$32.0^{a(a)}$	**8.6**
Mean		*68.3*	*58.3*	*56.4*		*34.6*	*35.4*	*32.5*	
LSD		***16.4***	***8.4***	***6.1***		***10.6***	***10.3***	***13.0***	
	150 (F_1)	$76.7^{a(ab)}$	$88.3^{a(a)}$	$60.8^{a(b)}$	**15.8**	$31.8^{a(a)}$	$28.9^{a(a)}$	$28.3^{a(a)}$	**5.4**
'Pylaias'	300 (F_2)	$74.7^{a(ab)}$	$83.4^{ab(a)}$	$63.7^{a(b)}$	**16.4**	$35.0^{a(a)}$	$29.8^{a(a)}$	$33.5^{a(a)}$	**9.5**
	450 (F_3)	$77.5^{a(a)}$	$71.4^{b(a)}$	$64.8^{a(a)}$	**14.0**	$36.4^{a(a)}$	$31.1^{a(a)}$	$30.6^{a(a)}$	**8.2**
Mean		*76.3*	*81.0*	*63.1*		*34.4*	*29.9*	*30.8*	
LSD		***9.3***	***10.5***	***15.4***		***12.3***	***10.8***	***11.5***	
	150 (F_1)	$92.2^{a(a)}$	$92.4^{a(a)}$	$78.7^{a(a)}$	**16.9**	$30.0^{a(a)}$	$30.5^{a(a)}$	$30.6^{a(a)}$	**8.4**
'Clemson'	300 (F_2)	$99.2^{a(a)}$	$92.7^{a(a)}$	$71.4^{ab(b)}$	**14.6**	$30.0^{a(a)}$	$29.3^{a(a)}$	$27.4^{a(a)}$	**5.6**
	450 (F_3)	$92.2^{a(a)}$	$84.8^{a(a)}$	$60.0^{b(b)}$	**12.3**	$26.7^{a(a)}$	$31.3^{a(a)}$	$29.9^{a(a)}$	**7.3**
Mean		*94.5*	*89.9*	*70.0*		*28.9*	*30.3*	*29.3*	
LSD		***10.1***	***13.5***	***16.8***		***11.1***	***11.0***	***6.5***	
C x F									
(C x F_1)		*	*	*		ns	*	*	
(C x F_2)		*	*	ns		*	ns	*	
(C x F_3)		*	*	ns		*	ns	ns	

Mean separation by LSD test. Mean values in the same column for each cultivar separately followed by different letters differ significantly at $p = 0.05$. Means in each row for each seed characteristic separately followed by the same letter in parenthesis do not differ significantly at $p = 0.05$.

* = statistically significant ($p < 0.05$).

Table 5. Effect of N levels on seed characteristics from pods harvested from different plant parts of four okra cultivars (Experiment 2)

Cultivar (C)	N level (mg l^{-1}) (F)	Number of seeds/pod			LSD	100-seed weight (g)			LSD
		Upper	Middle	Lower		Upper	Middle	Lower	
	150 (F_1)	$70.7^{a(a)}$	$71.7^{a(a)}$	$65.5^{a(a)}$	**18.9**	$31.2^{ab(a)}$	$29.7^{a(ab)}$	$23.8^{a(b)}$	**6.1**
'Boyiatiou'	300 (F_2)	$70.0^{a(a)}$	$67.0^{ab(a)}$	$67.2^{a(a)}$	**5.6**	$30.3^{b(a)}$	$29.4^{a(a)}$	$28.6^{a(a)}$	**6.0**
	450 (F_3)	$68.0^{a(a)}$	$59.0^{b(a)}$	$68.2^{a(a)}$	**9.7**	$35.7^{a(a)}$	$31.8^{a(ab)}$	$28.7^{a(b)}$	**5.2**
Mean		*69.5*	*65.9*	*66.9*		*32.4*	*30.3*	*27.0*	
LSD		***19.4***	***8.1***	***6.6***		***5.4***	***5.7***	***6.2***	
	150 (F_1)	$56.5^{b(b)}$	$73.5^{a(a)}$	$69.7^{a(ab)}$	**13.5**	$35.6^{a(a)}$	$42.0^{a(a)}$	$36.5^{a(a)}$	**8.6**
'Veloudo'	300 (F_2)	$68.2^{ab(b)}$	$84.7^{a(a)}$	$61.0^{b(b)}$	**12.0**	$39.2^{a(a)}$	$37.5^{a(a)}$	$37.9^{a(a)}$	**8.9**
	450 (F_3)	$75.0^{a(a)}$	$67.0^{b(b)}$	$67.2^{ab(b)}$	**6.9**	$38.3^{a(a)}$	$45.1^{a(a)}$	$40.5^{a(a)}$	**9.0**
Mean		*66.5*	*75.0*	*65.9*		*37.7*	*41.5*	*38.3*	
LSD		***16.4***	***8.4***	***6.1***		***7.4***	***7.7***	***11.0***	
	150 (F_1)	$70.0^{a(a)}$	$63.0^{b(a)}$	$75.0^{a(a)}$	**9.8**	$33.6^{a(ab)}$	$38.7^{a(a)}$	$29.6^{a(b)}$	**8.5**
'Pylaias'	300 (F_2)	$77.7^{a(a)}$	$72.5^{ab(a)}$	$73.5^{a(a)}$	**6.3**	$37.9^{a(a)}$	$36.5^{a(a)}$	$29.6^{a(a)}$	**8.8**
	450 (F_3)	$66.5^{a(a)}$	$81.2^{a(a)}$	$82.5^{a(a)}$	**17.3**	$38.6^{a(a)}$	$32.2^{a(ab)}$	$25.7^{a(b)}$	**7.6**
Mean		*71.4*	*72.2*	*77.0*		*36.7*	*35.8*	*28.3*	
LSD		***9.3***	***10.5***	***15.4***		***9.7***	***7.9***	***7.0***	
	150 (F_1)	$86.5^{a(b)}$	$95.5^{a(ab)}$	$101.2^{a(a)}$	**11.5**	$31.0^{a(a)}$	$30.9^{a(a)}$	$26.6^{a(a)}$	**5.5**
'Clemson'	300 (F_2)	$88.5^{a(a)}$	$89.7^{a(a)}$	$86.7^{b(a)}$	**12.1**	$35.7^{a(a)}$	$32.2^{a(ab)}$	$27.7^{a(b)}$	**6.9**
	450 (F_3)	$80.5^{a(a)}$	$85.2^{a(a)}$	$83.0^{c(a)}$	**17.1**	$35.9^{a(a)}$	$33.0^{a(ab)}$	$25.6^{a(b)}$	**7.9**
Mean		*85.1*	*90.1*	*90.3*		*34.2*	*32.0*	*26.6*	
LSD		***10.1***	***13.5***	***16.9***		***7.2***	***6.8***	***6.5***	
C x F									
(C x F_1)		*	*	*		ns	*	*	
(C x F_2)		*	*	*		*	*	*	
(C x F_3)		*	*	ns		ns	*	*	

Mean separation by LSD test. Mean values in the same column followed by different letters differ significantly at $p = 0.05$. * = statistically significant ($p < 0.05$); ns = not significant. (a): letter in parenthesis for horizontal analysis.

3.7 100-Seed Weight

Seed size expressed as the 100 seed weight was not affected by N level or the position of the pod on the plant in any cultivar in Experiment 1 (Table 4). Similarly, in Experiment 2 the 100 seed weight was not affected by N level, but was invariably lower in pods from the lower part of the plant compared with those from the middle and upper parts, but not always to a statistically significant degree (Table 5).

3.8 Seed Moisture Content at Harvest and after Pod Drying

The moisture content of seeds extracted from pods immediately after harvest was not significantly affected by the pod position on the plant or by the N level in either experiment and ranged from 25.5-37.5% in Experiment 1 (Table 6) and 28.1-43.2% in Experiment 2 (Table 8).

When the pods were dried at room temperature for 15 days and the seeds then extracted, the moisture content of seeds from the upper pods was higher at the higher N levels in 'Boyiatiou', 'Pylaias' and 'Clemson' (not in 'Veloudo') in Experiment 1 (Table 7), but not in Experiment 2 (Table 9). On the other hand, in Experiment 1 the moisture content of seeds from dried pods harvested from the middle and lower regions of the plant were mostly

unaffected by N level (Table 7), whereas in Experiment 2 moisture content was higher at the higher N levels in 'Veloudo', 'Clemson' and 'Pylaias' (lower pods) and in 'Boyiatiou' and 'Clemson' (middle pods) (Table 9). Overall, there were no consistent differences in moisture content between seeds extracted from dried pods harvested from different regions of the plant (Tables 7, 9). During drying of the pods, seed moisture fell to 9.6-13.5% (Experiment 1) and 11.0-12.9% (Experiment 2).

Table 6. Effect of N levels on the moisture content and germination percentage of seeds extracted from the pods immediately after harvest in relation to plant part (Experiment 1)

Cultivar (C)	N level (mg l^{-1}) (F)	Seeds extracted from pods immediately after harvest							
		Moisture content at harvest (%)			LSD	Germination (%)			LSD
		Upper	Middle	Lower		Upper	Middle	Lower	
	150 (F_1)	$29.9^{a(ab)}$	$18.9^{a(b)}$	$34.5^{a(a)}$	12.5	$39.3^{a(a)}$	$43.4^{a(a)}$	$44.2^{a(a)}$	11.6
'Boyiatiou'	300 (F_2)	$31.4^{a(a)}$	$29.9^{a(a)}$	$30.2^{a(a)}$	15.0	$44.8^{a(a)}$	$46.8^{a(a)}$	$44.4^{a(a)}$	10.8
	450 (F_3)	$27.4^{a(a)}$	$27.8^{a(a)}$	$27.5^{a(a)}$	14.2	$47.6^{a(a)}$	$47.4^{a(a)}$	$46.7^{a(a)}$	10.2
Mean		*29.5*	*25.5*	*30.7*		*43.9*	*45.8*	*45.1*	
LSD		***14.8***	***13.5***	***13.5***		***10.8***	***12.1***	***9.5***	
	150 (F_1)	$31.3^{a(a)}$	$27.5^{a(a)}$	$29.3^{a(a)}$	13.4	$47.6^{a(b)}$	$65.1^{b(a)}$	$56.0^{a(ab)}$	13.2
'Veloudo'	300 (F_2)	$30.9^{a(a)}$	$25.5^{a(a)}$	$32.0^{a(a)}$	12.9	$48.3^{a(b)}$	$78.2^{a(a)}$	$58.3^{a(ab)}$	10.6
	450 (F_3)	$30.5^{a(a)}$	$30.3^{a(a)}$	$26.1^{a(a)}$	13.8	$52.9^{a(b)}$	$67.0^{ab(a)}$	$58.5^{a(b)}$	8.6
Mean		*30.9*	*27.7*	*29.1*		*49.6*	*70.1*	*57.6*	
LSD		***13.3***	***13.6***	***13.1***		***9.8***	***12.3***	***10.6***	
	150 (F_1)	$35.7^{a(a)}$	$33.6^{a(a)}$	$35.7^{a(a)}$	19.5	$64.4^{a(a)}$	$65.9^{a(a)}$	$64.5^{a(a)}$	11.1
'Pylaias'	300 (F_2)	$39.4^{a(a)}$	$30.1^{a(a)}$	$33.4^{a(a)}$	17.7	$68.1^{a(a)}$	$68.4^{a(a)}$	$67.7^{a(a)}$	11.9
	450 (F_3)	$37.6^{a(a)}$	$32.6^{a(a)}$	$31.1^{a(a)}$	17.1	$77.1^{a(a)}$	$75.1^{a(a)}$	$73.2^{a(a)}$	15.4
Mean		*37.5*	*32.1*	*33.4*		*69.8*	*69.8*	*68.4*	
LSD		***18.4***	***17.2***	***18.7***		***13.2***	***13.3***	***12.3***	
	150 (F_1)	$33.3^{a(a)}$	$30.7^{a(a)}$	$31.8^{a(a)}$	17.1	$75.0^{a(a)}$	$75.4^{a(a)}$	$73.8^{a(a)}$	13.6
'Clemson'	300 (F_2)	$41.6^{a(a)}$	$30.9^{a(a)}$	$32.0^{a(a)}$	18.1	$75.9^{a(a)}$	$74.2^{a(a)}$	$71.3^{a(a)}$	13.2
	450 (F_3)	$35.3^{a(a)}$	$34.6^{a(a)}$	$32.6^{a(a)}$	16.4	$78.1^{a(a)}$	$76.0^{a(a)}$	$78.1^{a(a)}$	15.1
Mean		*36.7*	*32.0*	*32.1*		*76.3*	*75.2*	*74.4*	
LSD		***16.9***	***17.3***	***17.5***		***14.3***	***13.5***	***14.2***	
C x F									
(C x F_1)		ns	ns	ns		*	*	*	
(C x F_2)		ns	ns	ns		*	*	*	
(C x F_3)		ns	ns	ns		*	*	*	

Mean separation by LSD test. Mean values in the same column followed by different letters differ significantly at $p = 0.05$. * = statistically significant ($p < 0.05$); ns = not significant. (a): letter in parenthesis for horizontal analysis.

Table 7. Effect of N levels on the moisture content and germination percentage of seeds extracted from the pods 15 days after harvest in relation to plant part (Experiment 1)

Cultivar (C)	N level (mg l^{-1}) (F)	Seeds extracted from pods 15 days after harvest							
		Moisture content at harvest (%)			LSD	Germination (%)			LSD
		Upper	Middle	Lower		Upper	Middle	Lower	
	150 (F_1)	$12.2^{b(a)}$	$13.2^{a(a)}$	$13.3^{a(a)}$	1.5	$46.3^{a(c)}$	$49.4^{b(b)}$	$54.0^{a(a)}$	1.5
'Boyiatiou'	300 (F_2)	$13.6^{ab(ab)}$	$12.6^{a(b)}$	$14.4^{a(a)}$	1.0	$51.3^{a(b)}$	$54.0^{ab(a)}$	$54.5^{a(a)}$	1.0
	450 (F_3)	$14.0^{a(a)}$	$12.9^{a(a)}$	$12.8^{a(a)}$	3.1	$55.5^{a(b)}$	$62.2^{a(a)}$	$65.0^{a(a)}$	3.1
Mean		*13.2*	*12.9*	*13.5*		*51.0*	*55.2*	*57.8*	
LSD		***1.4***	***1.4***	***3.0***		***8.9***	***10.2***	***12.1***	
	150 (F_1)	$10.9^{b(ab)}$	$11.9^{a(a)}$	$8.8^{b(b)}$	1.0	$55.8^{a(a)}$	$61.2^{b(a)}$	$55.8^{b(a)}$	1.0
'Veloudo'	300 (F_2)	$9.8^{a(b)}$	$11.2^{a(a)}$	$9.4^{b(b)}$	1.3	$58.5^{a(b)}$	$63.8^{b(a)}$	$62.4^{ab(a)}$	1.3
	450 (F_3)	$10.3^{b(a)}$	$9.1^{b(b)}$	$10.8^{a(a)}$	0.9	$63.0^{a(c)}$	$72.1^{a(a)}$	$67.0^{a(b)}$	0.9
Mean		*10.3*	*10.7*	*9.6*		*59.1*	*65.7*	*61.7*	
LSD		***1.0***	***1.3***	***0.9***		***9.5***	***8.6***	***9.7***	
	150 (F_1)	$10.4^{b(a)}$	$9.5^{b(a)}$	$10.1^{a(a)}$	1.0	$71.9^{a(ab)}$	$71^{a(b)}$	$72.5^{a(a)}$	1.0
'Pylaias'	300 (F_2)	$10.6^{b(a)}$	$10.8^{a(a)}$	$10.9^{a(a)}$	0.7	$74.9^{a(b)}$	$78.5^{a(a)}$	$73.2^{a(c)}$	0.7
	450 (F_3)	$12.1^{a(a)}$	$9.8^{b(b)}$	$11.0^{a(ab)}$	1.2	$80.4^{a(a)}$	$79.6^{a(ab)}$	$78.5^{a(b}$	1.2
Mean		*11.0*	*10.0*	*10.6*		*75.7*	*76.3*	*74.7*	
LSD		***1.0***	***0.9***	***1.1***		***14.3***	***14.5***	***14.4***	
	150 (F_1)	$9.7^{b(a)}$	$9.8^{b(a)}$	$10.4^{a(a)}$	0.9	$82.3^{a(a)}$	$78.3^{a(a)}$	$79.8^{a(a)}$	14.6
'Clemson'	300 (F_2)	$11.2^{a(a)}$	$11.7^{a(a)}$	$10.4^{a(a)}$	1.2	$81.4^{a(a)}$	$79.2^{a(a)}$	$76.1^{a(a)}$	14.1
	450 (F_3)	$10.4^{a(a)}$	$10.7^{a(a)}$	$10.2^{a(a)}$	1.2	$80.9^{a(a)}$	$81.7^{a(a)}$	$81.5^{a(a)}$	15.2
Mean		*10.4*	*10.7*	*10.3*		*81.5*	*79.7*	*79.1*	
LSD		***1.0***	***1.1***	***1.2***		***15.0***	***14.4***	***14.5***	
C x F									
(C x F_1)		*	*	*		*	*	*	
(C x F_2)		*	*	*		*	*	*	
(C x F_3)		*	*	ns		*	*	*	

Mean separation by LSD test. Mean values in the same column followed by different letters differ significantly at $p = 0.05$. * = statistically significant ($p < 0.05$); ns = not significant. (a): letter in parenthesis for horizontal analysis.

3.9 Seed Germination

In Experiment 1, germination was not affected by N level when seeds were extracted from freshly harvested pods (i.e. without drying) and varied between 43.9 and 76.3%, being highest in 'Clemson' and lowest in 'Boyiatiou' irrespective of N level or the position of the pods on the plant (Table 6). A similar result was recorded in Experiment 2, where the germination ranged from 48.1% ('Boyiatiou') to 75.6% ('Clemson') (Table 8). With the exception of 'Veloudo' in Experiment 1 (where germination was higher for seeds from the pods in the middle compared to the lower region of the plant), no differences in germination were recorded in relation to the position of the pods on the plant (Tables 6 and 8).

Table 8. Effect of N levels on the moisture content and germination percentage of seeds extracted from the pods immediately after harvest in relation to plant part (Experiment 2)

Cultivar (C)	N level (mg l^{-1}) (F)	Seeds extracted from pods immediately after harvest							
		Moisture content at harvest (%)			LSD	Germination (%)			LSD
		Upper	Middle	Lower		Upper	Middle	Lower	
	150 (F_1)	31.1$^{a(a)}$	31.0$^{a(a)}$	33.6$^{a(a)}$	13.0	47.2$^{a(a)}$	47.1$^{b(a)}$	48.7$^{a(a)}$	8.6
'Boyiatiou'	300 (F_2)	31.0$^{a(a)}$	22.6$^{a(a)}$	30.8$^{a(a)}$	12.5	48.0$^{a(a)}$	51.2$^{ab(a)}$	49.0$^{a(a)}$	8.8
	450 (F_3)	35.5$^{a(a)}$	30.7$^{a(a)}$	30.1$^{a(a)}$	13.3	49.2$^{a(a)}$	57.2$^{a(a)}$	55.5$^{a(a)}$	10.9
Mean		*32.5*	*28.1*	*31.5*		*48.1*	*51.8*	*51.0*	
LSD		***13.5***	***13.0***	***12.4***		***8.5***	***9.5***	***10.4***	
	150 (F_1)	31.0$^{a(a)}$	30.6$^{a(a)}$	38.9$^{a(a)}$	13.5	51.9$^{a(a)}$	54.6$^{b(a)}$	56.6$^{a(a)}$	9.2
'Veloudo'	300 (F_2)	32.5$^{a(a)}$	24.5$^{a(a)}$	29.1$^{a(a)}$	13.0	53.9$^{a(a)}$	57.5$^{ab(a)}$	59.8$^{a(a)}$	10.5
	450 (F_3)	33.5$^{a(a)}$	30.6$^{a(a)}$	29.4$^{a(a)}$	12.4	58.9$^{a(a)}$	65.0$^{a(a)}$	61.7$^{a(a)}$	8.9
Mean		*32.3*	*28.5*	*32.4*		*54.9*	*59.0*	*59.3*	
LSD		***13.0***	***12.4***	***11.2***		***10.1***	***8.7***	***9.8***	
	150 (F_1)	33.7$^{a(a)}$	43.7$^{a(a)}$	35.7$^{a(a)}$	15.0	67.4$^{a(a)}$	70.7$^{a(a)}$	69.6$^{a(a)}$	11.6
'Pylaias'	300 (F_2)	33.0$^{a(a)}$	43.5$^{a(a)}$	31.5$^{a(a)}$	14.9	71.1$^{a(a)}$	72.3$^{a(a)}$	70.4$^{a(a)}$	13.1
	450 (F_3)	33.0$^{a(a)}$	42.5$^{a(a)}$	32.9$^{a(a)}$	14.7	72.3$^{a(a)}$	74.0$^{a(a)}$	69.9$^{a(a)}$	14.5
Mean		*33.2*	*43.2*	*33.3*		*70.2*	*72.3*	*69.9*	
LSD		***16.7***	***13.6***	***14.2***		***13.8***	***12.9***	***12.5***	
	150 (F_1)	40.2$^{a(a)}$	32.8$^{a(a)}$	26.3$^{a(a)}$	14.9	67.9$^{a(a)}$	72.6$^{a(a)}$	66.9$^{a(a)}$	16.2
'Clemson'	300 (F_2)	39.7$^{a(a)}$	40.4$^{a(a)}$	33.5$^{a(a)}$	11.8	71.5$^{a(a)}$	76.0$^{a(a)}$	70.2$^{a(a)}$	17.7
	450 (F_3)	38.4$^{a(a)}$	29.0$^{a(a)}$	29.5$^{a(a)}$	14.3	71.1$^{a(a)}$	78.3$^{a(a)}$	74.3$^{a(a)}$	16.5
Mean		*39.4*	*34.0*	*29.7*		*70.1*	*75.6*	*70.4*	
LSD		***13.8***	***13.1***	***14.3***		***16.3***	***16.0***	***18.0***	
C x F									
(C x F_1)		ns	ns	*		*	*	*	
(C x F_2)		ns	*	ns		*	*	*	
(C x F_3)		ns	*	ns		*	*	*	

Mean separation by LSD test. Mean values in the same column followed by different letters differ significantly at $p = 0.05$. * = statistically significant ($p < 0.05$); ns = not significant. (a): letter in parenthesis for horizontal analysis.

Table 9. Effect of N levels on the moisture content and germination percentage of seeds extracted from the pods 15 days after harvest in relation to plant part (Experiment 2)

Cultivar (C)	N level (mg l^{-1}) (F)	Seeds extracted from pods 15 days after harvest							
		Moisture content at harvest (%)			LSD	Germination (%)			LSD
		Upper	Middle	Lower		Upper	Middle	Lower	
	150 (F_1)	$12.8^{a(a)}$	$11.4^{b(a)}$	$11.4^{a(a)}$	1.3	$47.5^{b(a)}$	$54.5^{b(a)}$	$54.5^{a(a)}$	9.2
'Boyiatiou'	300 (F_2)	$12.9^{a(a)}$	$11.6^{b(b)}$	$12.0^{a(ab)}$	1.0	$52.2^{ab(a)}$	$57.4^{ab(a)}$	$59.3^{a(a)}$	10.4
	450 (F_3)	$13.2^{a(b)}$	$15.8^{a(a)}$	$12.6^{a(b)}$	2.5	$57.5^{a(a)}$	$65.6^{a(a)}$	$63.3^{a(a)}$	11.1
Mean		*12.9*	*12.9*	*12.0*		*52.4*	*59.1*	*59.0*	
LSD		***0.9***	***2.4***	***1.4***		***9.5***	***9.9***	***11.3***	
	150 (F_1)	$11.5^{a(ab)}$	$12.3^{a(a)}$	$10.9^{b(b)}$	1.2	$58.5^{b(a)}$	$62.1^{b(a)}$	$60.9^{a(a)}$	9.3
'Veloudo'	300 (F_2)	$11.2^{a(a)}$	$9.7^{b(b)}$	$12.4^{a(a)}$	1.2	$62.8^{ab(a)}$	$66.9^{ab(a)}$	$64.3^{a(a)}$	10.3
	450 (F_3)	$10.5^{a(b)}$	$11.8^{a(ab)}$	$13.0^{a(a)}$	1.4	$68.0^{a(a)}$	$72.9^{a(a)}$	$69.9^{a(a)}$	10.1
Mean		*11.0*	*11.2*	*12.1*		*63.1*	*67.3*	*65.0*	
LSD		***1.3***	***0.8***	***1.6***		***9.0***	***10.0***	***10.7***	
	150 (F_1)	$11.4^{b(a)}$	$12.1^{a(a)}$	$11.1^{b(a)}$	0.8	$70.0^{a(a)}$	$71.8^{a(a)}$	$73.5^{a(a)}$	11.8
'Pylaias'	300 (F_2)	$14.9^{a(a)}$	$12.1^{a(b)}$	$11.7^{b(b)}$	2.3	$72.7^{a(a)}$	$76.0^{a(a)}$	$68.0^{a(a)}$	15.8
	450 (F_3)	$10.6^{b(b)}$	$11.1^{b(b)}$	$12.4^{a(a)}$	0.6	$74.6^{a(a)}$	$75.5^{a(a)}$	$73.1^{a(a)}$	15.0
Mean		*12.3*	*11.7*	*11.7*		*72.4*	*74.4*	*71.5*	
LSD		***2.2***	***0.7***	***0.9***		***13.4***	***14.4***	***15.1***	
	150 (F_1)	$11.2^{a(a)}$	$11.9^{b(a)}$	$10.0^{b(b)}$	0.9	$73.5^{a(a)}$	$75.1^{a(a)}$	$71.3^{a(a)}$	16.7
'Clemson'	300 (F_2)	$11.9^{a(a)}$	$11.7^{b(a)}$	$11.8^{a(a)}$	1.4	$74.5^{a(a)}$	$78.2^{a(a)}$	$73.0^{a(a)}$	17.6
	450 (F_3)	$12.0^{a(b)}$	$13.2^{a(a)}$	$11.6^{a(b)}$	1.0	$75.3^{a(a)}$	$79.7^{a(a)}$	$77.1^{a(a)}$	16.8
Mean		*11.7*	*12.2*	*11.1*		*74.4*	*77.6*	*73.8*	
LSD		***1.3***	***1.1***	***0.9***		***15.8***	***16.3***	***18.9***	
C x F									
(C x F_1)		*	ns	*		*	*	*	
(C x F_2)		*	*	ns		*	*	ns	
(C x F_3)		*	*	*		*	*	ns	

Mean separation by LSD test. Mean values in the same column followed by different letters differ significantly at $p = 0.05$. * = statistically significant ($p < 0.05$); ns = not significant. (a): letter in parenthesis for horizontal analysis.

When pods were dried prior to seed extraction, germination was not affected by N in seeds from the upper and lower pods in Experiment 1, but in 'Boyiatiou' and 'Veloudo' was higher for seeds from pods in the middle region of the plant from the 450 ppm N treatment than the 150 ppm N treatment (Table 7). In Experiment 2, a similar result was recorded, with differences in germination being recorded only for 'Boyiatiou' and 'Veloudo' (higher germination in seeds from 450 ppm N compared to 150 ppm N for pods harvested from the upper and middle part s of the plant (Table 9). In Experiment 1, germination was higher in seeds from the lower pods compared to the upper pods for 'Boyiatiou' (at all N levels) and 'Veloudo' (450 ppm N), but lower in 'Pylaias' (300 ppm N) (Table 7). In Experiment 2, no effect of pod position was observed in relation to the germination of seeds from dried pods (Table 9).

3.10 Germination of Seeds in Relation to Storage

In both experiments, the percent germination of seeds of all cultivars was higher after storage for 18 months at room temperature compared with the initial germination, irrespective of whether seeds were extracted from pods

immediately or 15 days after harvest (Figures 4 and 5). It is noteworthy that whereas in both experiments the germination of 'Boyiatiou' and 'Veloudo' was initially < 65% (i.e. lower than the minimum acceptable level, FEK 140/2000) (the official standard for commercial purpose is 85%), following storage it reached 75-85% ('Boyiatiou') and 85-90% ('Veloudo').

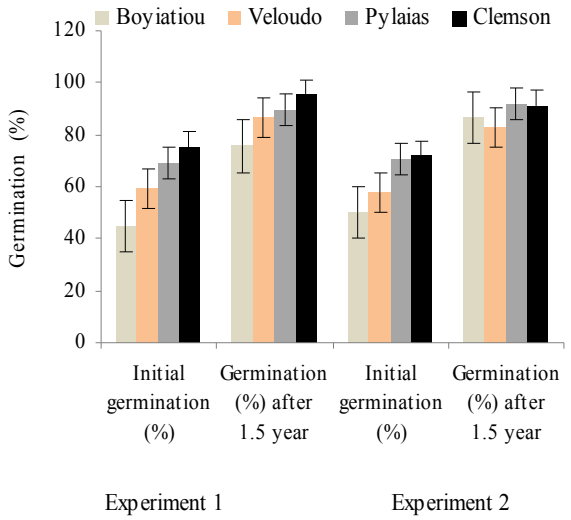

Figure 4. The germination percentage of seeds of four okra cultivars extracted from pods immediately after harvest in Experiments 1 and 2: (a) Initial germination, (b) After storage for 18 months

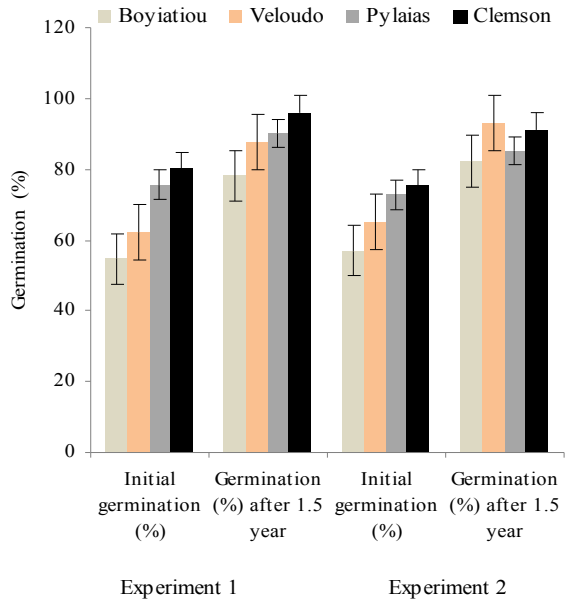

Figure 5. The percent germination of seeds of four okra cultivars extracted from pods 15 days after harvest in Experiments 1 and 2: (a) Initial germination, (b) After storage for 18 months

4. Discussion

The beneficial effects of N application on okra growth and pod production are well documented, especially for fresh production (Prabhakar, Hebbar, & Gayathri, 2009) and to a lesser extent for seed crops (Dutta & Naik, 2009). There is, however, little available information in the literature concerning the effect of N on pod characteristics and seed quality.

From the results of the present experiments, it is clear that although significant differences in flower induction

and pod set existed between cultivars, overall there was little or no effect of N application on these two characteristics. In both experiments, flower induction was highest in 'Clemson' and lowest in 'Boyiatiou' and although pod set increased at 450 ppm N application in 'Boyiatiou', this did not occur in the other cultivars. It should be noted, however, that pod set in 'Boyiatiou' was much lower than that in the other cultivars: for example mean pod set was 7.3 and 6.3 pods per plant in 'Boyiatiou' compared with 24.3 and 21.2 pods per plant in 'Clemson' (Experiments 1 and 2, respectively). This result is somewhat surprising since 'Boyiatiou' is a local cultivar (Koutsos, 2009) and might be expected to be better adapted to Greek climatic conditions, e.g. light, temperature and humidity, than the American cv. 'Clemson'. Although okra is considered to be a short-day plant (Bhatt & Srinivasa Rao, 2009), cv. 'Boyiatiou' (like 'Pylaias') is classified as day-neutral (Koutsos, 2009). Similarly, although pod length and diameter varied between the cultivars, these characteristics were largely unaffected by N level, despite reports to the contrary by Majanbu et al. (1985) and Singh (1995), irrespective of the position of the pods on the plant, presumably because pod dimensions are genetically determined rather than influenced by cultivation conditions (Raji, 1994).

The number of seeds per pod was significantly higher in the pods from the middle and upper part of the plant in 'Clemson' and 'Pylaias', as well as in 'Boyiatiou' (at 450 ppm N) and 'Veloudo' (at 150 ppm N) in Experiment 1 (Table 4), but only in 'Veloudo' (350 and 450 ppm N) in Experiment 2. Although Majanbu et al. (1985) and Moniruzzaman and Quamruzzaman (2009) reported a positive effect of N on the number of seeds per fruit, in our experiments the N level had virtually no effect on seed number in any cultivar in both experiments. It is possible that these differences relate to the cultivars used in each study, or to differences in climatic conditions. Moreover, these authors did not study the effect of pod position on seed number, which the data of Table 4 show to be a significant factor in defining seed number per pod.

No significant effect of N on seed size (100-seed weight) was detected, irrespective of the pod position at harvest (upper, middle and lower) or cultivar. This result contrasts with those of Uddin, Mondal, Samsuzzaman, and Siddique (2006) and Moniruzzaman and Quamruzzaman (2009) who reported a positive effect of N on mean 100 seed weight. The percent germination of seeds extracted immediately after harvest or after storage of pods for 15 days before seed extraction was not affected by N application; nor was seed moisture content. The differences in germination ability between cultivars appear to relate to variation of seed hardness at harvest since pods were harvested at a mature stage. As noted elsewhere, 'Boyiatiou' is especially susceptible to seed hardness, which accounts for its lower percent germination (49.7%) in comparison with 'Clemson' (77.7%) (Passam & Rekoumi, 2009).

It is interesting that the only consistently positive effects of N application on seed germination were detected in 'Boyiatiou'. Although frequently insignificant, an increase in germination was nevertheless observed irrespective of the position of the pod on the plant. The increase of germination was relatively higher in the case of seeds extracted from pods after storage for 15 days at room temperature, i.e. in seeds with a lower moisture content than those extracted immediately after harvest. Seed hardness in okra is known to relate to moisture content and the rate of seed drying (Demir, 1997), whereas in other species N delays flowering and fruit maturation (George, 1987). It may be that in 'Boyiatiou', high N levels delay the rate of seed maturation and thereby reduce the incidence of hard seeds. It is surprising, however, that the germination of 'Boyiatiou' was not affected by the method of seed extraction since the higher moisture content of seeds extracted from pods immediately after harvest might have been expected to lead to higher germination compared with seeds from dried pods (mean moisture content 25-32% and 12-13%, respectively). Perhaps, the drying of pods prior to seed extraction permitted after-ripening of seeds, as occurs in aubergine (*Solanum melongena* L.) (Passam, Theodoropoulou, Karanissa, & Karapanos, 2010).

The effect of pod position on seed quality in okra has already been reported by Purquerio, Lago, and Passos (2010). Yadav et al. (2001) observed higher seed germination from pods harvested from lower positions on the okra plant, while Prabhakar, Hedge, Srinivas, and Doijode (1985) and Naik, Vogeesha, Bhanuprakash & Padmini (2004) reported that seeds harvested from okra pods produced at the lower nodes (up to the 8th node) had better quality. Overall, our data do not support these reports (with a few exceptions, Tables 6 and 7), indicating that under the hot and dry conditions of Thessaly during the summer, the rate of seed drying is similar (and therefore the occurrence of hard seeds) for pods, irrespective of their position on the plant.

Seed germination in all the cultivars increased significantly after storage for 18 months, irrespective of the method of seed extraction. Mohammadi, Khah, and Bannayan (2011) reported a similar positive effect of seed storage for 12 months on okra germination. In this way, seed lots of 'Boyiatiou' that were initially below the minimum requirement for germination (FEK 140/2000), attained an acceptable level of germination after storage, according to Greek market standards for seed trading.

5. Conclusions

The present experiments provide new information on the seed quality of four cultivars of okra in relation to N level and the part (upper, lower and middle) of the plant from which harvest took place. N application generally increased flowering, but pod set increased only in 'Boyiatiou'. Pod dimensions (length and diameter) were largely unaffected by N level, irrespective of the position of the pods on the plant, as was the 100-seed weight and seed germination. The slight (insignificant) increase in seed germination of 'Boyiatiou' in response to N is worthy of further study in view of the susceptibility of this cultivar to seed hardness. There was no benefit of pod after-ripening, but seed storage for 18 months at room temperature proved to be a positive way to improve seed quality, especially in 'Boyiatiou'.

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