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# Influence of different rates of nitrogen fertilizer on growth, yield and fruit quality of sweet pepper (*Capsicum annum* L. var. California Wander)

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## ABSTRACT

**Purpose:** Vegetables are important sources of carbohydrates, proteins, vitamins, and minerals. The fruit of bell pepper is one of the most important commercial crops in the world. This study was conducted to determine the effects of nitrogen (N) doses on the growth and yield of sweet pepper (*Capsicum annum* L. var. California Wander) under field conditions. **Research Method:** Treatments consisted of 0, 50, 100 and 150 kg N $ha^{-1}$. Plant height, leaf chlorophyll index, flower number, yield, fruit seed number, 1000 seed weight and vitamin C were assessed at immature and mature stages. **Findings:** Nitrogen doses affected significantly plant vegetative growth (plant height, lateral stem number, and leaf chlorophyll). The highest length and number of lateral stem and number of leaf were obtained in plants treated with 100 kg N $ha^{-1}$. The results indicated that reproductive factors (weight and volume of fruit, plant yield, and 1000 seed weight) were influenced by N fertilizer. It was observed that fertilization with 150 kg N $ha^{-1}$ resulted to the highest fruit weight and fruit yield. Although there were no significant differences in vitamin C content among treated plants with different nitrogen levels at a mature stage, it was shown significant differences between treated and control plants. **Research limitations:** Evaluation of more sources of N fertilizer such as ammonium nitrate or ammonium sulfate on growth and yield of bell pepper possibly had a better outcome of this project. **Originality/value:** Results showed that N fertilization has a strong impact on the vegetative, flowering and reproductive growth of pepper plants under field conditions.

## INTRODUCTION

Vegetables are important sources of carbohydrates, proteins, vitamins, and minerals. Pepper (Capsicum annum L.) which belongs to Solanaceae, is known as a vegetable and consumed both as fresh and dehydrated spices. Pepper is a good source of vitamins A, C, E, B1, and B2, potassium, phosphorus, and calcium. Moreover, it is one of the valuable medicinal plants in pharmaceutical industries because of high amounts of antioxidant, capsaicin and capsantinas main active substances (Bosland & Vostava, 2000).

The yield depends upon certain factors. Among these proper, balanced nutrition plays a significant role. Nitrogen (N) is a major constituent of several of the most important substances, which occur in plants. It is of outstanding importance among the essential elements in the N compounds comprised from 40 to 50% of the dry matter of the protoplasm, the living substance of plant cells (Togun et al., 2003). For this reason, N is required in relatively large quantities for growth processes in plants. It follows directly from that without an adequate supply of N appreciable growth cannot take place and that plants must remain stunted and relatively underdeveloped when N is deficient. Nitrogen is known to promote production, partitioning, and accumulation of dry matter in crop plant (Akanbi et al., 2007). The productivity of pepper is highly responsive to N fertilizer. Tumbar and Niikam (2004) reported that N fertilizer increased fruit weight, yield and fruit number of chili peppers. Aroiee and Omidbaigi (2004) reported that N fertilizer increased leaf chlorophyll of pumpkin and had a linear relationship between leaf chlorophyll content and leaf N concentration. Devi et al. (2002) found better fruit girth, fruit weight and fruit yield level of eggplant with the application of 120 kg per hectare. Gulser (2005) reported that an increasing N fertilizer levels increased the yield, stem length and leaf surface area in spinach. Lorenzoni et al. (2016) reported better fruit firmness, fruit weight and fruit yield of bell pepper were obtained from the application of 150 kg per hectare. Ayodele et al. (2015) reported N application significantly increased plant height, number of branches, number of leaves, leaf area and ripe fruit yield (number and weight) of hot pepper up 75 kg N $ha^{-1}$. It is well-known that adequate N is required by pepper for satisfactory growth, development, and yield. Thus the main aims of this experiment were to determine the influence of N fertilizer on growth, yield, and quality of bell pepper.

## MATERIALS AND METHODS

### Plant preparation

This investigation was conducted during the 2014-2015 growing season at the experimental field of the Agricultural Faculty, University of Birjand (latitude 32° 53 N, longitude 59° 13 E and 1470 m elevation), Iran. Annual rainfall ranges are between 91 and 120 mm and mean annual relative humidity is 37%. The average maximum and minimum temperature during the trial period were 40.2 °C and 19.4 °C, respectively. The experimental field was cleared, ploughed, harrowed and divided into plots. A soil sample (0-30 cm depth) was taken with auger after the site had been prepared for cultivation. The sample was analysed for physical and chemical properties using standard laboratory procedures described by Mylavapus and Kennelley (2002) and data shown in Table 1. Pepper seeds (*Capsicum annum* L. var. California Wander) were established in a greenhouse in large trays with a 1:1 mixture of sand and soil. Irrigation was done after sowing when necessary. Six-week-old pepper plants were hand-transplanted into well-prepared beds in the field on March 26, 2014. The spacing between rows was 0.75 m and spacing between plants was 0.25 m. Triple super phosphate

(TSP) and potassium sulfate fertilizers as constant doses were applied as a source of phosphorus and potassium, respectively. Phosphorus ($P_2O_5$) and potassium ($K_2O_5$) were applied 100 and 50 kg per hectare each at the time of soil preparation. All practical managements including mulching, weeding, staking and other horticultural operations were done traditionally.

### Treatments

Treatments consisted of four levels of nitrogen (0, 50, 100 and 150 kg N $ha^{-1}$). The source for nitrogenous fertilizer was urea that was split into three equal parts and applied at ten days after transplanting (DAP) as basal and remaining portions were used as top dressing at 30 and 50 DAP.

### Measurements

Ten plants in each replication were used to assess plant height, leaf number, number and length of lateral stem and internodes length at three growing stages including vegetative, flowering and fruiting.

Leaf chlorophyll index (SPAD value) was measured by a portable chlorophyll meter, SPAD-502 (Minolta Corporation, Ramsey, NJ). Leaves samples were oven dried at 75 C for 72 h to the constant weight dry weight for each plant was weighed using digital balance and recorded in gram (Basel & Mahadeen, 2008). Days to 1st flowering were estimated for each plot and number of flowers per plant was evaluated based on the method by Remison (1997).

Mature fruits were harvested at weekly intervals to assess the number and volume of fruits ($cm^3$), and fruit yield per plant (g/plant). Fruit weight (g) per plant was measured by dividing total fruit yield by the number of plants. Fruit yield per hectare was obtained through conversion of the net plot yield. Vitamin C (AA) was determined based on the quantitative discolouration of 2, 6-dichlorophenolindophenol (Merck, Darmstadt, Germany) titrimetric method as described in AOAC methodology No. 967.21 (AOAC, 2000).

### Experimental design and statistical analysis

The experiment was arranged in a completely randomized block design (CRBD) with four treatments and three replications, each replication with ten plants. Data were analysed using SAS program (ver 9.4, 2013), means were compared by Duncan's multiple range test (DMRT) at 5% level of confidence.

## RESULTS AND DISCUSSION

### Plant height and lateral stems height

Nitrogen fertilizer application at all stages (vegetative, flowering and reproductive) increased plant height (Table 2). The highest level of N fertilizer (150 kg N $ha^{-1}$) produced the tallest plants and the shortest plants formed in the control (vegetative and reproductive stages). However, no significant difference was found among three treatments: 50, 100 and 150 kg N $ha^{-1}$ at vegetative and flowering stages. The obtained results were in agreement with findings of previous reports (Bar et al., 2001; Boroujerdnia & Alemzadeh, 2007; Bowen & Frey, 2002; Geti et al., 2008). The height of plant can be considered as one of the indices of plant vigor ordinarily and it depends upon vigor and growth habit of the plant. Soil nutrients are also very important for the height of plants. So, a higher dose of N increased plant height (Pervez et al., 2004).

**Table 1.** Soil characteristics of the experimental field

| Soil characteristics | N (ppm) | P (ppm) | K (ppm) | pH | Clay (%) | Silt (%) | Sand (%) |
|---|---|---|---|---|---|---|---|
| Values | 630 | 14 | 290 | 7.1 | 19 | 41 | 40 |

**Table 2.** Effect of nitrogen fertilizer on vegetative characteristics of sweet pepper

| Treatment (kg N ha$^{-1}$) | Plant height (cm) | | | Lateral stem length (cm) | | Lateral stem No. |
|---|---|---|---|---|---|---|
| | Veg.‡ | Flower | Rep. | Veg. | Rep. | Veg. |
| 0 (control) | 18.59$^{b}$† | 26.42$^{b}$ | 37.84$^{c}$ | 10.67$^{b}$ | 23.09$^{b}$ | 10.00$^{b}$ |
| 50 | 20.00$^{a}$ | 29.26$^{a}$ | 40.17$^{b}$ | 11.51$^{a}$ | 24.76$^{a}$ | 10.76$^{a}$ |
| 100 | 19.92$^{a}$ | 29.76$^{a}$ | 40.42$^{ab}$ | 12.17$^{a}$ | 25.26$^{a}$ | 11.17$^{a}$ |
| 150 | 20.09$^{a}$ | 28.34$^{ab}$ | 41.67$^{a}$ | 11.59$^{a}$ | 25.51$^{a}$ | 10.92$^{a}$ |

‡Veg.: Vegetative stage; Flower: Flowering stage; Rep.: the Reproductive stage.
†Within each column, the same letter indicates no significant difference between treatments at 5% levels.

The effects of N fertilizer on the stem characteristics of pepper was significant. The maximum number and height of lateral stems with 11.17 and 12.17cm were obtained at 100 kg N ha$^{-1}$ (at the vegetative stage), but there were no significant among three treatments: 50, 100 and 150 kg N ha$^{-1}$ (Table 2). Similar results were observed by previous studies (Bar et al., 2001; Khattak et al., 2001). As N level decreased number and length of lateral stems also decreased and plant receiving no N produced minimum number and length of lateral stems.

## Leaf number

Nitrogen fertilizer level significantly affected leaf number (at vegetative and reproductive stages), and the highest leaf number was related to the fourth treatment (150 kg N ha$^{-1}$) with 26.09 and 90.76 leaves while the lowest was related to the control treatment with 23.92 and 82.67 leaves. However, at the flowering stage, no significant differences were found among treatments (Table 3), as reported by previous studies (Ayodele, 2002; Boroujerdnia & Alemzadeh, 2007). Each increase in inorganic fertilizer dose tended to increase the number of leaves per plant compared with control. This variation might be due to the availability of nutrients especially N and could be due to the improvement of soil water holding capacity as mentioned earlier by Roe and Cornforth (2000).

## Leaf chlorophyll index

The effect of nitrogen fertilizer level on leaf chlorophyll index was significant. Results indicated the lowest leaf chlorophyll index by control plants at all stages (vegetative, flowering and reproductive), but there were no significant between nitrogen levels at all stages (Table 3). Similar results have been reported in investigations conducted by Aroiee and Omidbaigi (2004) in pumpkin, Bowen and Frey (2002) in pepper, Basela and Mahadeen, (2008) in broccoli and Geti et al. (2008) in tomato. A promotion effect of inorganic fertilizers on chlorophyll index might be attributed to the fact that N is a constituent of the chlorophyll molecule. Moreover, nitrogen is the main constituent of all amino acids in proteins and lipids that acting as a structural compound of the chloroplast (Basela & Mahadeen, 2008).

## Leaf dry matter content

A significant difference among the N treatments was found on the leaf dry matter content (Table 3). By increasing the N fertilizer rate the leaf dry matter content increased, but the difference between 50, 100 and 150 kg N ha$^{-1}$ treatments was not statistically significant at vegetative stage. The highest leaf dry matter content at all stages (vegetative, flowering and reproductive) was obtained at 150 kg N ha$^{-1}$ application (18.29, 23.29 and 24.02%, respectively) while the least leaf dry matter content was obtained in the control (16.61,19.64 and 20.42, respectively). Similarly, Magdalena (2003) reported that leaf dry matter content increased as N rate increased. Tei et al. (2000) also reported that increasing the rate of N fertilizer significantly increased the dry weight of leaves. Takebe et al. (1995) reported that increments in leaf dry weight may be due to a combination of N with plant matter produced during photosynthesis such as glucose, ascorbic acid, amino acids, and protein. It is suggested that nitrogen has a high influence on plant growth and development. Nitrogen is an important element for economic vegetable production and is especially required for successful production when grown in poor mineral soils.

**Days to 1st flowering**

The effect of nitrogen fertilizer level on days to 1st flowering was significant (Table 4). Days to flowering ranged from 47.84 days (control) to 45.26 days (50 Kg N ha$^{-1}$). Thus N treatments decreased the days to 1st flowering and treated plants flowered early than control (Table 4). Nitrogen deficiency retarded the vegetative as well as reproductive growth, which resulted in more days to flowering and fruit setting. Similarly, more N gave maximum days to flowering and fruit setting. It means N enhanced vegetative growth and reduced reproductive growth (Jilani et al., 2008), therefore, a fertilizer dose of 100 kg N per hectare proved better for minimum days to flowering, which leads to early fruit setting which was in agreement with findings of Satpal and Saimbhi (2003) in brinjal and Law and Egharevba (2009) in tomato.

**Node number to first flower, flower and fruit number at lateral stems**

The result of this experiment indicated that N fertilizer increased the number node to the first flower pepper (Table 4). The highest and lowest node number of the first flower was obtained at 100 kg N ha$^{-1}$ (11.09 nodes) and control (9.84 nodes), respectively. Flower and fruit number at lateral stems were significantly by N fertilizer (Table 4). The maximum number of flower (with 4.92) and fruit number (with 2.5) at lateral stems were observed in 50 and 100 kg N while the least number of flower and fruit number at lateral stems were recorded at control (with 4.09) and 150 kg N ha$^{-1}$ (with 2), respectively (Table 4). These results agreed with the findings of previous reports (Guohua et al., 2001; Olaniyi, 2008; Solvadore et al., 1997). Ali and Kelly (1992) suggested that the maintenance of vigorous vegetative growth from flower bud formation throughout fruit development might ensure sufficient assimilate supply to alleviate stress on growing processes in the developing buds. The increase of soil fertility delayed the commence of flowering and fruit set of sweet pepper but increased total fruit yield (Shrivastava, 1996).

**Table 3.** Effect of nitrogen fertilizer on leaf number, leaf chlorophyll index and leaf dry matter content of sweet pepper

| Treatment (kg N ha$^{-1}$) | Leaf No. | | Leaf chlorophyll index | | | Leaf dry matter content (g) | | |
|---|---|---|---|---|---|---|---|---|
| | Veg.‡ | Rep. | Veg. | Flower | Rep. | Veg. | Flower. | Rep. |
| 0 (control) | 23.92$^{b}$† | 82.76$^{c}$ | 55.68$^{b}$ | 62.67$^{b}$ | 61.81$^{b}$ | 16.61$^{b}$ | 19.46$^{c}$ | 20.42$^{c}$ |
| 50 | 25.42$^{ab}$ | 86.09$^{b}$ | 59.34$^{a}$ | 65.55$^{ab}$ | 65.49$^{a}$ | 17.55$^{a}$ | 21.39$^{b}$ | 22.88$^{b}$ |
| 100 | 25.76$^{a}$ | 87.51$^{b}$ | 59.74$^{a}$ | 65.27$^{ab}$ | 66.92$^{a}$ | 18.03$^{a}$ | 21.70$^{b}$ | 23.59$^{ab}$ |
| 150 | 26.09$^{a}$ | 90.76$^{a}$ | 60.59$^{a}$ | 66.99$^{a}$ | 64.48$^{ab}$ | 18.29$^{a}$ | 23.29$^{a}$ | 24.02$^{a}$ |

‡Veg.: Vegetative stage; Flower: Flowering stage; Rep.: the Reproductive stage.
†Within each column, the same letter indicates no significant difference between treatments at 5% levels.

**Table 4.** Effect of nitrogen fertilizer on reproductive characteristics of sweet pepper

| Treatment (kg N ha$^{-1}$) | Node number to the first flower | Days to 1st flowering | Flower number at the lateral stem | Fruit number at the lateral stem |
|---|---|---|---|---|
| 0 (control) | 9.84$^{b}$† | 47.84$^{a}$ | 4.09$^{c}$ | 1.84$^{b}$ |
| 50 | 10.84$^{a}$ | 45.26$^{b}$ | 4.92$^{a}$ | 2.17$^{ab}$ |
| 100 | 11.09$^{a}$ | 45.76$^{b}$ | 4.76$^{ab}$ | 2.51$^{a}$ |
| 150 | 11.00$^{a}$ | 46.76$^{ab}$ | 4.42$^{bc}$ | 2.00$^{b}$ |

†Within each column, the same letter indicates no significant difference between treatments at 5% levels.

### Fruit weight and fruit volume

This trial revealed that statistical significances differences existed among the treatments for average fruit weight and fruit volume. Data showed the highest fruit weight and volume was observed from 50 kg N ha$^{-1}$ (72.52 g) and 100 kg ha$^{-1}$ (157.9 cm$^3$) respectively, while the lowest (64.59 g, 141.7cm$^3$) was related to the control treatments (Table 5). These results are consistent with those reported by Magdalena (2003), Bar et al. (2001), Akanbi et al. (2007) and Aujla et al. (2007) who also reported that increasing the rate of N fertilizers increased the average fruit weight and fruit volume of pepper.

### Seed weight and 1000-seed weight

Total seed weight and 1000-seed weight significantly increased by N treatments compared with control. However, no significant difference was found between three treatments: 50, 100 and 150 kg N ha$^{-1}$ (Table 5). An adequate supply of N is essential for vigorous vegetative growth, seed formation and increase 1000 seed weight and optimum yield of pepper which was in agreement with findings of Olaniyi (2008) and Akanbi et al. (2007).

### Fruit number

The effect of N fertilizer levels on fruit number was significant. The lowest fruit number per plant was obtained by control (17.34) and 150 kg N ha$^{-1}$ (18.09), and this variable increased as N levels decreased from 150 to 50 kg (Table 5). Magdalena (2003), Tei et al. (2000) and Fernández-Luqueño et al. (2010) reported that increments in the N rate of the fertilizers increased the number of fruit in pepper.

### Yield

Nitrogen fertilization significantly increased yield per plant as compared to control. The highest yield in pepper was obtained as 1120 g/plant after application of 100 kg N ha$^{-1}$ and the lowest yield was obtained from control treatment (944 g/plant) (Table 5) that was in agreement with Tei et al. (2000), Tumbare et al. (2004) and Fernández-Luqueño et al. (2010). Increasing N levels of the fertilizers to 100 kg N ha$^{-1}$ significantly increased the yield of pepper as compared to control, while yield decreased at the highest N dose. This decrease in yield might be due to toxicity in the plant (Tabatabaie & Malakouti, 1997). The marked effect of N on yield might be due to the cumulative stimulating effect of N on the vegetative growth characters which form the base for flowering and fruiting

### Vitamin C

Although, the lowest vitamin C was observed in control at green and red fruit stages, however, increased by different levels of N compared with control (Table 5). As data showed, N fertilizer affected vitamin C content of fruit; an increment of N levels from 50 to 150 reduced vitamin C content at the green and red fruit stages (Table 5). Mozafar (1993) reported the positive and negative effects of N on vitamin C contents by fruits. Anita et al. (2009) who also reported that increasing the rate of N fertilizers increased vitamin C of pumpkin.

**Table 5.** Effect of nitrogen fertilizer on fruit quality characteristics of sweet pepper

| Treatment (kg N ha$^{-1}$) | Fruit F. W (g) | Fruit Vol. (cm$^3$) | Seed No/Fruit | 1000 Seed W. (g) | Vit-C (mg 100 g$^{-1}$) Green fruit | Vit-C (mg 100 g$^{-1}$) Red fruit | Yield/plant (g) | Total yield (Kg ha$^{-1}$) | Fruit No./ plant |
|---|---|---|---|---|---|---|---|---|---|
| 0 (control) | 64.59$^{c}$† | 141.7$^{c}$ | 125.3$^{b}$ | 5.02$^{b}$ | 131.7$^{c}$ | 198.3$^{b}$ | 944.0$^{c}$ | 5815.5$^{c}$ | 17.34$^{c}$ |
| 50 | 72.51$^{a}$ | 152.1$^{ab}$ | 138.5$^{a}$ | 5.40$^{a}$ | 135.1$^{a}$ | 203.2$^{a}$ | 1111$^{a}$ | 6561.5$^{a}$ | 18.76$^{ab}$ |
| 100 | 72.51$^{a}$ | 157.9$^{a}$ | 139.7$^{a}$ | 5.42$^{a}$ | 135.5$^{a}$ | 204.2$^{a}$ | 1120$^{a}$ | 6728.5$^{a}$ | 19.26$^{a}$ |
| 150 | 69.92$^{b}$ | 147.1b$^{c}$ | 141.3$^{a}$ | 5.26$^{a}$ | 133.0$^{b}$ | 201.2$^{ab}$ | 1029$^{b}$ | 6207.5$^{b}$ | 18.09$^{bc}$ |

†Within each column, the same letter indicates no significant difference between treatments at 5% levels.

## CONCLUSION

The results showed that N fertilization has a strong impact on the vegetative, flowering and reproductive growth of pepper plants under field conditions. Although there were no significant differences between N levels in almost all cases of variables, however, reproductive growth was improved with lower nitrogen levels. Thus, application of the low amount of N (50 kg ha$^{-1}$) is recommended for bell pepper production.

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# بررسی تأثیر سطوح مختلف کود نیتروژن بر رشد، عملکرد و کیفیت میوه فلفل شیرین رقم کالیفرنیا واندر(*Capsicum annum* L. var. California Wander)

محمد حسین امینی فرد و حسن بیات

**چکیده:**

**سبزیجات منبع مهم کربوهیدرات‌ها، پروتئین‌ها، ویتامین‌ها و مواد معدنی هستند. فلفل دلمه‌ای، یکی از مهم‌ترین محصولات تجاری در جهان است. این تحقیق به منظور بررسی اثر غلظت‌های مختلف نیتروژن بر رشد و عملکرد فلفل شیرین رقم کالیفرنیا در شرایط مزرعه انجام شد. تیمارها شامل ۰، ۵۰، ۱۰۰ و ۱۵۰ کیلوگرم نیتروژن در هکتار از منبع اوره بود. ارتفاع بوته، شاخص کلروفیل برگ، تعداد گل، عملکرد، تعداد بذر میوه، وزن هزار دانه و ویتامین C در مرحله نابالغ و بالغ بررسی شد. افزایش میزان نیتروژن به طور قابل توجهی باعث افزایش رشد رویشی گیاهان (ارتفاع بوته، تعداد ساقه جانبی و کلروفیل برگ) شد. بیشترین طول و تعداد ساقه جانبی و تعداد برگ از گیاهان تیمار شده با ۱۰۰ کیلوگرم نیتروژن در هکتار به دست آمد. نتایج نشان داد که صفات زایشی (وزن و حجم میوه، عملکرد گیاه و وزن هزار دانه) تحت تأثیر کود نیتروژن قرار گرفتند. بالاترین وزن و عملکرد میوه از تغذیه با کود ۱۵۰ کیلوگرم نیتروژن در هکتار بدست آمد. اگر چه اختلاف معنی‌داری در محتوای ویتامین C در گیاهان تحت تیمار با سطوح مختلف نیتروژن در مرحله بالغ وجود نداشت، ولی بین گیاهان تیمار شده و شاهد تفاوت معنی‌داری وجود داشت. بنابراین نتایج نشان داد که تغذیه نیتروژن تأثیر قابل توجهی بر رشد رویشی، گلدهی و عملکرد گیاهان فلفل شیرین در شرایط مزرعه دارد.**

**کلمات کلیدی:** کیفیت میوه، عملکرد میوه، نیتروژن، فلفل شیرین