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# EFFECT OF BORON AND CALCIUM TREATMENTS ON YIELD AND FRUIT QUALITY OF 'Le-Conte' PEARS

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**ABSTRACT:** *This study was conducted during the 2005 and 2006 seasons to evaluate the response of 'Le-Conte' pear (Pyrus communis L) trees, grown in sandy soil, to foliar and soil application of B and/or Ca. Boric acid (B) and chelated calcium (Ca) were applied at the rates of 8 or 16 g foliar B, 16 or 32 g foliar Ca, 8 g B + 16 g foliar Ca, 16 g B + 32 g foliar Ca, and 80 g B + 160 g Ca soil application in a randomized complete block design with a control treatment without B or Ca application. Foliar and soil treatments were applied 3 times at stages of bud swelling, 70% flowering and when fruit reached the hazelnut-size. Data were recorded on the number of spur leaves; spur leaf area; leaf area; leaf and spur leaf chlorophyll content; total spur leaf area; leaf N, P, K, Ca, and B content; nodes, and leaf content of total and reducing sugar; total indoles and total phenols; percentages of fruit set and retained fruits; fruit yield/tree; and fruit weight, size, firmness, polar and equatorial diameters, soluble solids concentration (SSC) and titratable acidity (TA). Most characters were fairly consistent in their response to B and Ca treatments. While the 80 g boric acid + 160 g chelated Ca soil application treatment resulted in the lowest significant values of spur leaf chlorophyll content in 2006 and fruit firmness in the two studied seasons; it gave the highest significant response in most other characters in both seasons; including number of spur leaves; spur leaf area; total spur leaf area; leaf area; leaf chlorophyll content; leaf N, P, Ca and B content; nodes and leaf total and reducing sugars and total indoles content; percentages of fruit set and retained fruits; fruit yield/tree; and fruit weight, size, polar and equatorial diameters, and SSC. The control treatment was opposite to the 80 g B + 160 g Ca soil treatment in most of the above listed characters. Additionally, it gave the largest significant values of nodes and leaf total phenols content and fruit TA. As a general trend, the 80 g B + 160 g Ca treatment was followed by the 16 g B + 32 g foliar Ca, and then by the 8 g B + 16 g foliar Ca. These 3 treatments were followed, in most characters measured, by the 8 and 16 g foliar B treatments. The 16 g and 32 g foliar Ca treatment occupied, in most characters, a position between foliar B treatments and the control. It was recommended to treat pear trees grown in sandy soil by the application to the soil of 80 g boric acid and 160 g chelated Ca/tree 3 times at stages of bud swelling, 70% flowering, and when fruits reach the hazelnut-size for the improvement of yield and fruit quality.*

**Key words :** Boron nutrition, Calcium nutrition, pears, Pyrus communis, fruit yield, fruit quality.

## INTRODUCTION

A major effect of B nutrition in fruit trees is its role in fruit set (Faust, 1989). Early research indicated that B is necessary for flower bud formation (Kamali and Childers, 1970), production of pollen grains (Argawala *et al.*, 1981), and pollen tube growth (Dickinson, 1978). Roles proposed for B in plants include functions in sugar transport, cell-wall synthesis and lignification, cell-wall structure, carbohydrate metabolism, nitrogen metabolism, RNA metabolism, respiration, indole acetic acid and phenol metabolism, and membrane transport (Blevins and Lukaszewski, 1998). In vivo pollen germination and tube growth of almond [(*Prunus dulicis* Mill.) D.A. Webb (syn. *P. amygdalus* Batsh)] were enhanced by foliar applied B (Nyomora *et al.*, 2000).

A minimum boron threshold value of 30-40 ppm in late summer mid-shoot leaves has been established for most deciduous fruit tree species (Mills and Jones, 1996). Yield may increase following foliar B application even for trees that exhibit leaf B concentrations within the desirable range (Chaplin *et al.*, 1977).

The goal of foliar B programs is to increase B in flower buds, which may be achieved by B application in the early spring. Such applications increased flower cluster and early season leaf B concentrations in 'Scartlet Gala' apple trees (Peryea *et al.*, 2003).

Boron application increased fruit set in Italian prune (Chaplin *et al.*, 1977; Callan *et al.*, 1978; Hanson *et al.*, 1985; Hanson, 1991). Also, prebloom foliar boron and zinc applications enhanced cropping of 'Empire' and 'McIntosh' apple (*Malus domestica* L.) orchards (Stover *et al.*, 1999). Likewise, foliar B application to 'Le-Conte' pear (*Pyrus communis* L.) trees at full bloom increased fruit set, yield, fruit quality characters (SSC, weight, and volume), and leaf content of most macro and micro elements, including N, P, K, Ca, and B (Kabeel *et al.*, 1999).

Though foliar B application to almond trees in February increased initial fruit set, applications made immediately postharvest in September induced optimal effect on tissue B concentration, fruit set, and yield (Nyomora *et al.*, 1999).

Foliar applications of B to 'Conference' pear trees before full bloom or after harvest increased fruit set and fruit yield, but had no effect on tree vigor, mean fruit weight, firmness, SSC, or titratable acidity of fruits at harvest. Foliar B sprays before full bloom or after harvest increased B concentrations in flowers, and both leaves and fruitlets at 40 days after flowering and increased Ca in leaves at 120 days after full bloom (Wojcik and Wojcik, 2003).

Sanchez and Righetti (2005) applied boric acid to 'Delicious' apple trees at the rate of 16 g/tree as either postharvest foliar or soil application. Postharvest foliar B was efficiently transported from the leaves to storage tissues for the next year's growth, while soil-applied B remained mostly in the roots, as very little was translocated to the above-grown portions of the tree at full bloom.

Postharvest B sprays of 'Jonagold' apple trees improved flower B status, fruit set, and tree yield (Wojcik, 2006).

Wojcik and Treder (2006) recommended drip boron fertigation of 'Jonagold' apple trees from the stage of bud burst to petal fall at a rate of 0.5 g/tree at 3-4-day-intervals. This treatment improved B status in flowers and leaves of current season shoots, fruit set, and yield; but had no effect on mean fruit weight, titratable acidity, or firmness.

Likewise, calcium plays an essential role in pollen germination and pollen tube growth (Brewbaker and Kweck, 1963). Calcium sprays of 'Anjou' pear trees increased fruit Ca concentration and yield (Rease and Drake, 1995) and sprays during fruit development increased fruit flesh firmness and harvest (Gerasapoulos and Richardson, 1997). Also, foliar calcium application increased Ca concentration in 'Jonagold' apple fruits (Wojcik, 2005). Meanwhile, it had no significant effect on flesh firmness or SSC of 'Sinap Orlovskiy' apple fruits (Lanauskas and Kvikliene, 2006).

B, Ca, or B + Ca sprays of Lowbush blueberry (*Vaccinium angustifolium* Ait) increased pollen germination by 8%, while B treatment alone resulted in more seeds per berry (Chen *et al.,* 1998).

Therefore, this study was conducted to evaluate the effect of foliar and soil treatment with B and/or Ca on fruit set, yield, and fruit quality of 'Le-Conte' pear trees.

## MATERIALS AND METHODS

This study was conducted on 15-year-old 'Le-Conte' pear trees grafted on *P. communis* rootstocks and grown 4 × 6 m apart in sandy soil in a private farm at km 76 Cairo/Alexandria desert road, Egypt during the 2005 and 2006 seasons. Different trees were used in the two seasons. The objective was to improve yield and quality of 'Le-Conte' pear through foliar or soil application of B and/or Ca. Six foliar treatments were by spraying with boric acid (17% B) at 8 or 16 g/tree, chelated Ca (12% $Ca^{++}$) at 16 or 32 g/tree, and boric acid + chelated Ca at, respectively, 8 + 16 or 16 + 32 g/tree in 5 liters of water. One soil treatment was by the application of 80 g boric acid + 160 g chelated Ca in 5 liters of water/tree. Control trees were left without B or Ca treatment. However, normal orchard practices included fertigation with 286 kg calcium nitrate/fed. Over 21 applications during the period from 1$^{st}$ March to 11$^{th}$ May. In the two seasons, treatments were made at three developmental stages, viz, (a) bud swelling (26$^{th}$ and 28$^{th}$ of February, respectively), (b) 70% flowering (12$^{th}$ and 14$^{th}$ of March, respectively), and (c ) hazelnut-size of developing fruits (13$^{th}$ and 12$^{th}$ of April, respectively).

A randomized complete block design with 8 treatments (6 foliar and 1 soil applications of B and/or Ca + control) with 3 replicates was used. Each experimental unit consisted of one tree. Selected trees for the study were nearly homogenous in growth. Tree measurements were made on 10 2-year-old branches around each tree in both seasons. Data were recorded on: (a) number and area of spur leaves in late August in the two seasons. A CL203 area meter (CID, Inc., U.S.A.) was used for spur leaf area determination, based on measurements recorded on 10 spur leaves; (b) leaf area determined in late August using the same method as described for spur leaves; (c ) spur leaf and leaf chlorophyll content on late August in the two seasons using a SPAD 502 chlorophyll meter (Minolta Corporation, Ramsey, N.J., U.S.A.) based on readings recorded on 10 leaves as above; (d) fruit set percentage based on data obtained on the number of open flowers and the number of set fruits; (e) percentage of retained fruits per shoot at picking date in both seasons; and (f) fruit yield/tree. Fruits were harvested on 3$^{rd}$ and 7$^{th}$ of August, 2005 and 2006, respectively.

Fruit measurements were conducted on 15 harvested fruits/experimental unit and included fruit weight, size, firmness using a pressure tester with a ¼ inch plunger (Catalytic Generators, Inc., Norfolk, VA, U.S.A.), polar and equatorial diameters, soluble solids concentration (SSC), and titratable acidity (TA) as percent malic acid (AOAC, 1975).

Leaf samples taken for N, P, K, Ca, and B analyses were collected from the middle portion of branches. Each sample consisted of 40 leaves. They were washed several times with tap water, rinsed with distilled water, and then dried at 70°C to a constant weight. Dried samples were ground in a stainless steel rotary knife mill, screened through 20 mesh screen, and 0.5 g dried samples were taken for analysis.

Chemical analysis included measurements of leaf content of N, P, K, Ca and B and node and also leaf content of total and reducing sugars, total indoles, and total phenols. Samples were taken for various measurements during late August in both seasons. Leaf measurements were made in the second season only. N was analyzed by the Kjeldahl and digestion method as described by Jackson (1973), while P was measured by using the ammonium molybdate method as described by Trough and Mayer (1949) and K using wet digestion (Piper, 1950) and flame photometer method according to Brown and Lilleland (1946). Ca and B were determined by using the Atomic Absorption Spectrophotometer (3300) according to Wild *et al.* (1985).

Extraction of total and reducing sugars and total indoles and phenols was conducted according to Daniel and George (1972). Five grams of sample was each extracted with 85% ethyl alcohol at 0°C for 72 hrs with ethanol being changed every 24 hrs (Daniel and George, 1972).

The *p*-dimethyl amino benzaldehyde test (Larsen *et al.,* 1962) was used for determination of total soluble indoles. Readings were recorded using a spectrophotometer at 530 nm.

The Folin-Denis reagent was used for colorimetric determination of total phenols according to Daniel and George (1972).

The reducing and total sugars content was measured using the 3,5-dinitrosalisylic acid method as described by Miller (1959).

Data obtained were statistically analyzed, and mean separation was according to the LSD test (Steel and Torrie, 1981).

## RESULTS

### Foliage characters :

B and Ca treatments induced significant effects on the number of spur leaves, individual and total spur leaf area (Table 1), leaf area, and leaf and spur leaf chlorophyll content (Table 2).

In both seasons of the study, the number of spur leaves, spur leaf area and total spur leaf area were significantly the highest in the soil application treatment with combined B and Ca. Values of the respective characters were 8.1 and 7.7 leaves, 27.1 and 29.3 $cm^2$, and 219.5 and 225.6 $cm^2$ in the two seasons, respectively. Meanwhile, all foliar B or B + Ca treatments ranked second in the number of spur leaves, while foliar Ca sprays and the control treatments were significantly the least in this character in both seasons. While, the control treatment was significantly the least in spur leaf area, with other treatments being intermediate in 2006; it was not significantly different from all other treatments, except those which included treatment with B + Ca whether though foliar (16 + 32 g/tree) or soil (80 + 160 g/tree) application. The results were reflected in the total spur leaf area, with B + Ca soil application being significantly the highest and the control treatment being significantly the smallest, but without significant difference from foliar Ca treatments in both seasons (Table 1).

In both seasons, leaf area was significantly the largest with the soil application treatment of 80 g boric acid and 160 g chelated Ca/tree (being 40.86 and 47.52 $cm^2$ in the two seasons, respectively). The second significantly largest leaf area was obtained, in both seasons, in all foliar B treatments whether alone or in combination with Ca. Foliar treatment with Ca alone came third in order of leaf area in both seasons, and was not significantly different from the control (Table 2).

No specific trend was noted regarding chlorophyll content (SPAD reading) in both leaves and spur leaves. The top significant treatments in chlorophyll content were : (a) 16 g foliar Ca and 16 g B + 32 g Ca for leaf chlorophyll content in 2005; (b) 16 g foliar B, 32 g foliar Ca, and 80 g B + 160 g Ca soil application for leaf chlorophyll content in 2006; (c ) 16 g foliar B + 32 g foliar Ca, 8 g B + 16 g foliar Ca and 80 g B + 160 g Ca soil application for spur leaf chlorophyll content in 2005; and (d) 16 g foliar B and 32 g foliar Ca for spur leaf chlorophyll content in 2006. Though the control treatment was significantly the lowest in chlorophyll content whether in leaves or spur leaves in both years, it was not significantly different from some other treatments, viz., (a) 8 and 16 g foliar B and 32 g foliar Ca for leaves in 2005 and (b) 8 g foliar B, 32 g foliar Ca, and all combined B and Ca treatments, whether by foliar or soil application, for spur leaves in both seasons, in addition to 16g foliar Ca in 2006 (Table 2).

Table (1): Effect of boron and calcium treatments on number and area of spur leaves of 'Le-Conte' pear trees.

| Treatments | No. of spur leaves | | Spur leaf area ($cm^2$) | | Total spur leaf area ($cm^2$) | |
|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| Foliar application | | | | | | |
| B (8g) | 5.6 | 6.4 | 19.5 | 23.7 | 109.2 | 151.7 |
| B (16g) | 5.6 | 6.9 | 21.0 | 23.8 | 117.6 | 164.2 |
| Ca (16g) | 4.8 | 5.9 | 18.5 | 22.2 | 88.8 | 130.9 |
| Ca (32g) | 4.8 | 5.5 | 19.6 | 22.8 | 94.0 | 125.4 |
| B (8g) + Ca (16g) | 5.9 | 6.8 | 21.6 | 23.4 | 127.4 | 159.1 |
| B (16g) + Ca (32g) | 6.3 | 7.4 | 24.8 | 25.0 | 156.2 | 185.0 |
| Soil application | | | | | | |
| B (80g) + Ca(160g) | 8.1 | 7.7 | 27.1 | 29.3 | 219.5 | 225.6 |
| Control | 4.5 | 5.5 | 16.9 | 18.0 | 76.1 | 99.0 |
| LSD (0.05) | *0.858* | *1.055* | *5.28* | *3.05* | *33.49* | *29.69* |

Table (2) : Effect of boron and calcium treatments on leaf area and leaf and spur leaf chlorophyll content of 'Le-Conte' pear trees.

| Treatments | Leaf area | | Leaf chlorophyll (SPAD reading) | | Spur leaf chlorophyll (SPAD reading) | |
|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| Foliar application | | | | | | |
| B (8g) | 32.97 | 39.67 | 52.50 | 54.11 | 51.92 | 55.94 |
| B (16g) | 33.69 | 39.69 | 54.07 | 56.84 | 60.47 | 58.88 |
| Ca (16g) | 28.69 | 32.15 | 59.55 | 54.64 | 60.85 | 53.36 |
| Ca (32g) | 29.35 | 32.74 | 51.51 | 58.22 | 59.39 | 61.34 |
| B (8g) + Ca (16g) | 33.36 | 40.37 | 55.37 | 54.69 | 59.15 | 53.49 |
| B (16g) + Ca (32g) | 35.04 | 42.51 | 61.75 | 54.26 | 55.57 | 54.14 |
| Soil application | | | | | | |
| B (80g) + Ca (160g) | 40.86 | 47.52 | 55.22 | 57.00 | 58.69 | 54.20 |
| Control | 25.06 | 32.07 | 49.32 | 50.85 | 55.09 | 52.50 |
| LSD (0.05) | *5.06* | *4.42* | *5.32* | *3.25* | *4.81* | *4.17* |

## Chemical analysis :

Leaf N, P, K, Ca, and B content and nodes and leaf analyses of total and reducing sugars, total indoles, and total phenols were all significantly affected by applied treatments (Tables 3-5).

Leaf N content was significantly the highest in the 16 g B + 32 g Ca foliar and 80 g B + 160 g Ca soil application treatments in both seasons (respectively for the two treatments 2.73 and 2.93% and 2.78 and 2.88% in the two seasons, respectively), in addition to the 8 g B and 32 g Ca foliar treatment in 2005 and 16 g Ca foliar in 2006. The control treatment was significantly the least in leaf N content in both seasons (1.69 and 1.98%, respectively). Other treatments were intermediate in their effect on leaf N content (Table, 3).

The top significant treatments in leaf P content were 16 g B + 32 g foliar Ca in 2005 (0.20%) and 8 g foliar B (0.18%), and 80 g B + 160 g soil Ca (0.18 and 0.19%) in both seasons. The control treatment was the least in leaf P content, but without significant differences from 16 g B and 16 g Ca foliar treatments in 2005, and 16 g Ca and 16 g B + 32 g Ca foliar treatments in 2006. Other treatments were intermediate in their effect (Table 3).

Leaf K content was significantly the highest in the 80 g B + 160 g Ca soil treatment in 2005 (1.38%) and the 16 g B + 32 g Ca foliar treatment in 2006 (1.39%). The second highest significant treatments were the 8 g B foliar in 2005 and 80 g B + 160 g Ca soil in 2006. The least significant treatments were the 16 g Ca foliar, followed by 32 g Ca foliar in 2005 and 16 g foliar Ca in 2006.

Other treatments, including the control, were intermediate in their effect on leaf K content (Table 3).

The top and second highest significant treatments in leaf Ca content were, respectively, 32 g Ca foliar and 80 g B + 160 g Ca soil in 2005 and 80 g B + 160 g Ca soil and 16 g B + 32 g Ca foliar application in 2006. The control treatment was the least significant in leaf Ca content in both seasons, with other treatments being intermediate (Table 3).

In both seasons, the highest significant treatment in leaf B content was 80 g B + 160 g Ca soil application (53.4 and 55.1 ppm, respectively), the second highest was the 16 g B + 32 g Ca foliar, followed by the 16 g B foliar, then by the 8 g B + 16 g Ca foliar. Other treatments, arranged in a significant descending order in both seasons, were 8 g B foliar, 32 g Ca foliar, 16 g Ca foliar, and the control which was significantly the least in leaf B content (Table 3).

Table (3) : Effect of boron and calcium treatments on leaf N, P, K, Ca and B analysis of 'Le-Conte' pear trees.

| Treatments | N (%) | | P (%) | | K (%) | | Ca (%) | | B (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| Foliar application | | | | | | | | | | |
| B (8g) | 2.93 | 2.44 | 0.18 | 0.18 | 1.27 | 1.24 | 0.80 | 0.94 | 48.10 | 46.30 |
| B (16g) | 2.28 | 2.62 | 0.16 | 0.17 | 1.18 | 1.15 | 0.94 | 0.85 | 53.10 | 52.40 |
| Ca (16g) | 2.59 | 2.93 | 0.16 | 0.12 | 0.98 | 1.09 | 1.06 | 0.94 | 41.30 | 44.20 |
| Ca (32g) | 2.93 | 2.24 | 0.18 | 0.17 | 1.00 | 1.21 | 1.29 | 1.10 | 47.40 | 45.50 |
| B (8g) + Ca (16g) | 2.27 | 2.28 | 0.18 | 0.15 | 1.18 | 1.27 | 1.13 | 0.92 | 50.30 | 49.60 |
| B (16g) + Ca (32g) | 2.73 | 2.93 | 0.20 | 0.15 | 1.21 | 1.39 | 1.20 | 1.28 | 53.30 | 54.40 |
| Soil application | | | | | | | | | | |
| B (80g) + Ca (160g) | 2.78 | 2.88 | 0.18 | 0.19 | 1.38 | 1.35 | 1.27 | 1.35 | 53.40 | 55.10 |
| Control | 1.69 | 1.98 | 0.15 | 0.13 | 1.06 | 1.21 | 0.87 | 0.69 | 39.10 | 40.20 |
| LSD (0.05) | *0.29* | *0.18* | *0.02* | *0.02* | *0.02* | *0.02* | *0.02* | *0.06* | *0.02* | *0.02* |

Table (4) : Effect of boron and calcium treatments on nodes and leaves content of total and reducing sugars of 'Le-Conte' pear trees.

| Treatments | Total sugars (%) | | | Reducing sugars (%) | | |
|---|---|---|---|---|---|---|
| | Nodes | | Leaves | Nodes | | Leaves |
| | 2005 | 2006 | 2006 | 2005 | 2006 | 2006 |
| Foliar application | | | | | | |
| B (8g) | 1.410 | 2.269 | 3.084 | 0.691 | 0.784 | 1.038 |
| B (16g) | 1.647 | 2.506 | 2.177 | 0.816 | 0.884 | 1.166 |
| Ca (16g) | 1.213 | 2.182 | 2.401 | 0.624 | 0.710 | 1.062 |
| Ca (32g) | 1.445 | 2.317 | 2.794 | 0.678 | 0.788 | 1.110 |
| B (8g) + Ca (16g) | 1.786 | 2.734 | 3.270 | 0.764 | 0.786 | 1.171 |
| B (16g) + Ca (32g) | 1.988 | 2.765 | 3.598 | 0.563 | 0.817 | 1.238 |
| Soil application | | | | | | |
| B (80g) + Ca (160g) | 2.364 | 3.369 | 4.376 | 0.920 | 0.823 | 1.669 |
| Control | 1.564 | 1.800 | 1.757 | 0.524 | 0.643 | 0.359 |
| LSD (0.05) | *0.018* | *0.020* | *1.072* | *0.021* | *0.018* | *0.022* |

Table (5) : Effect of boron and calcium treatments on nodes and leaves content of total indoles and phenols of 'Le-Conte' pear trees.

| Treatments | Total indoles (mg/100g) | | | Total phenols (%) | | |
|---|---|---|---|---|---|---|
| | Nodes | | Leaves | Nodes | | Leaves |
| | 2005 | 2006 | 2006 | 2005 | 2006 | 2006 |
| Foliar application | | | | | | |
| B (8g) | 1.780 | 1.162 | 3.183 | 0.736 | 0.757 | 1.033 |
| B (16g) | 1.861 | 1.773 | 3.259 | 0.733 | 0.723 | 0.712 |
| Ca (16g) | 1.740 | 1.725 | 2.257 | 0.656 | 0.684 | 0.622 |
| Ca (32g) | 1.879 | 1.820 | 2.296 | 0.728 | 0.708 | 0.774 |
| B (8g) + Ca (16g) | 1.951 | 1.855 | 3.397 | 0.757 | 0.772 | 0.723 |
| B (16g) + Ca (32g) | 1.789 | 2.016 | 4.156 | 0.637 | 0.757 | 0.680 |
| Soil application | | | | | | |
| B (80g) + Ca (160g) | 2.622 | 2.034 | 4.613 | 0.590 | 0.764 | 0.050 |
| Control | 1.092 | 1.205 | 0.718 | 0.791 | 0.785 | 1.060 |
| LSD (0.05) | *0.359* | *0.018* | *0.018* | *0.019* | *0.018* | *0.020* |

The 80 g B + 160 g Ca soil application was, by far, the highest significant treatment in node and leaf total and reducing sugars content in both seasons. The 16 g B + 32 g Ca foliar treatment was significantly the second highest in nodes total sugars content in both seasons, leaf total sugars content in 2006 without significant differences from the top treatment, and leaf reducing sugars content in 2006. The 8 g B + 16 g Ca foliar treatment ranked third in these characters in both seasons. The control treatment was significantly the lowest in nodes total sugars content in 2006, leaf total sugars content in 2006 (but without significant differences from the 16 g B, 16 g Ca, and 32 g Ca foliar treatments), nodes reducing sugars content in 2005, and leaf reducing sugars content in 2006. Other treatments were intermediate in these characters (Table 4).

Total indoles content was significantly the highest in both nodes and leaves in the 80 g B + 160 g Ca soil application treatment in both seasons. In 2005, the control treatment was significantly the lowest in nodes total indoles content, while all other treatments were intermediate. In 2006, the 16 g B + 32 g Ca foliar treatment was significantly the 2$^{nd}$ highest in both nodes and leaf total indoles content, while the control was significantly the lowest in leaf total indoles content, and the 8 g foliar B treatment being the lowest in nodes total indoles content, and control treatment the second lowest. Other treatments were intermediate (Table 5).

The control treatment was significantly the top in total phenols content in both nodes and leaves in both seasons of the study. The 80 g B + 160 g Ca soil application treatment was significantly the lowest in total phenols content in nodes in 2005 and in leaves in 2006, while the 16 g foliar Ca treatment was the lowest in nodes total phenols content in 2006. Other treatments were intermediate without a specific trend (Table 5).

## Fruit yield and its components :

Fruit set percentage, percentage of retained fruits, and fruit yield/tree were significantly affected by treatments applied in both seasons. All characters were, by far, significantly highest in the 80 g B + 160 g Ca soil treatment (being, respectively 11.13 and 12.73%, 90.50 and 92.20% and 93.46 and 87.06 kg/tree) and significantly the lowest in the control treatment (being, respectively, 4.5 and 3.45%, 59.17 and 56.33%, and 40.71 and 44.18 kg/tree) in both years, but without significant differences from some other treatments. The 16 g foliar B, 8 g B + 16 g foliar Ca and 16 g B + 32 g foliar Ca were not significantly different from the top treatment in both fruit set percentage in 2005 and total yield/tree in 2006. In 2005, the 16 g foliar Ca treatment was not significantly different from the control in fruit set percentage. All foliar treatments applied in 2005 and 16 g foliar B, 8 g B + 16 g foliar Ca, and 16 g B + 32 g foliar Ca in 2006 were not significantly different from the top treatment in fruit yield. In all other cases (characters and years), the 16 g B + 32 g foliar Ca treatment ranked second. Other foliar B treatments, whether alone or in combination with Ca, occupied mostly a third ranking position in fruit set percentage, while no specific trend was noted for this 3rd ranking position regarding percentage of retained fruits (Table 6).

Table (6) : Effect of boron and calcium treatments on yield components of 'Le-Conte' pear trees.

| Treatments | Fruit set (%) | | Retained fruits (%) | | Fruit yield/tree (Kg) | |
|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| Foliar application | | | | | | |
| B (8g) | 8.22 | 9.0 | 74.00 | 76.00 | 80.14 | 75.83 |
| B (16g) | 10.20 | 9.96 | 78.67 | 80.00 | 86.86 | 79.23 |
| Ca (16g) | 6.40 | 5.87 | 66.37 | 68.77 | 76.24 | 73.57 |
| Ca (32g) | 6.73 | 7.5 | 70.00 | 73.00 | 79.08 | 74.60 |
| B (8g) + Ca (16g) | 10.23 | 9.40 | 80.67 | 83.00 | 89.22 | 82.67 |
| B (16g) + Ca (32g) | 10.73 | 11.50 | 83.33 | 86.33 | 90.34 | 84.20 |
| Soil application | | | | | | |
| B (80g) + Ca (160g) | 11.13 | 12.73 | 90.50 | 92.20 | 93.46 | 87.06 |
| Control | 4.5 | 3.45 | 59.17 | 56.33 | 40.71 | 44.18 |
| LSD (0.05) | *1.95* | *1.12* | *4.15* | *4.34* | *17.27* | *8.28* |

## Fruit quality attributes :

All fruit quality attributes measured; viz., fruit weight, size, firmness, polar and equatorial diameters, SSC, and TA; were significantly affected by applied treatments (Tables 7 and 8).

With a few exceptions, the 80 g B + 160 g Ca soil application treatment was significantly the highest in fruit weight, size, polar and equatorial diameters, and SSC; and it was significantly the lowest in fruit firmness and TA; while the control treatment occupied, significantly, the opposite trend, except with fruit firmness in which the 32 g foliar Ca was the top treatment, followed by the 16 g foliar Ca. The 16 g B + 32 g Ca foliar treatment was not significantly different from the 80 g B + 160 g Ca soil treatment in fruit weight, size, firmness and equatorial diameter in both seasons; and in fruit polar diameter and TA in 2006. Additionally, the 80 g B + 160 g Ca soil treatment, was not significantly different from the 8 g B + 16 g foliar Ca and 16 g B + 32 g foliar Ca in fruit size in 2005 and TA in 2006, and also in equatorial diameters and fruit firmness in both seasons. Likewise, the top treatment was not significantly different from 16 g B + 32 g foliar Ca in fruit size and polar diameter in 2006 and fruit weight in both seasons (Tables 7 and 8).

In other treatments, the trend observed varied slightly depending on characters measured. The 16 g and sometimes the 8 g foliar B treatments, with or without Ca, were particularly effective in improving various fruit quality attributes measured. Foliar Ca applied alone was either not significantly different from some of the foliar B treatments in one or both seasons as in fruit weight, not significantly different from the control treatment as in SSC, or occupied significantly intermediate position between other treatments and the control as in most other characters in either or both seasons (Tables 7 and 8).

Table (7): Effect of boron and calcium treatments on fruit weight, size and firmness of 'Le-Conte' pear trees.

| Treatments | Fruit weight (g.) | | Fruit size ($cm^3$) | | Firmness ($lb/inch^2$) | |
|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| Foliar application | | | | | | |
| B (8g) | 149.1 | 160.1 | 146.4 | 158.9 | 19.1 | 20.7 |
| B (16g) | 168.4 | 175.4 | 166.4 | 174.5 | 19.0 | 20.1 |
| Ca (16g) | 151.1 | 172.5 | 152.9 | 171.7 | 21.3 | 22.7 |
| Ca (32g) | 153.5 | 175.1 | 150.1 | 174.4 | 22.4 | 24.5 |
| B (8g) + Ca (16g) | 173.2 | 191.5 | 174.2 | 191.1 | 18.0 | 19.0 |
| B (16g) + Ca (32g) | 175.7 | 207.5 | 174.4 | 203.3 | 16.9 | 18.5 |
| Soil application | | | | | | |
| B (80g) + Ca (160g) | 184.2 | 214.3 | 185.4 | 213.3 | 17.4 | 18.4 |
| Control | 113.7 | 95.9 | 113.1 | 91.7 | 20.2 | 22.4 |
| LSD (0.05) | *10.5* | *15.3* | *13.8* | *15.2* | *2.4* | *1.7* |

Table (8) : Effect of boron and calcium treatments on fruit diameters, soluble solids concentration (SSC) and titratable acidity of 'Le-Conte' pear trees.

| Treatments | Polar diameter (cm) | | Equatorial diameter (cm) | | SSC (%) | | Titratable acidity (%) | |
|---|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| Foliar application | | | | | | | | |
| B (8g) | 7.9 | 8.1 | 6.2 | 6.4 | 12.0 | 12.5 | 0.28 | 0.24 |
| B (16g) | 7.4 | 8.3 | 6.3 | 6.5 | 12.0 | 12.5 | 0.29 | 0.26 |
| Ca (16g) | 7.0 | 8.1 | 5.7 | 6.0 | 11.5 | 11.3 | 0.34 | 0.36 |
| Ca (32g) | 7.6 | 8.2 | 6.0 | 6.2 | 11.0 | 11.44 | 0.32 | 0.33 |
| B (8g) + Ca (16g) | 7.3 | 8.4 | 6.5 | 6.8 | 12.5 | 12.6 | 0.33 | 0.22 |
| B (16g) + Ca (32g) | 7.5 | 9.1 | 5.9 | 6.8 | 12.5 | 12.6 | 0.24 | 0.26 |
| Soil application | | | | | | | | |
| B (80g) + Ca (160g) | 8.2 | 9.3 | 6.3 | 7.1 | 13.3 | 13.9 | 0.30 | 0.26 |
| Control | 6.5 | 6.4 | 5.6 | 4.9 | 11.0 | 11.3 | 0.39 | 0.40 |
| LSD (0.05) | *0.6* | *0.6* | *0.5* | *0.4* | *0.2* | *0.5* | *0.02* | *0.06* |

## DISCUSSION AND CONCLUSIONS

The 80 g B + 160 g Ca, i.e., 80 g boric acid + 160 g chelated Ca soil application treatment of pear trees, resulted in the highest significant values of number of spur leaves, spur leaf area, and total spur leaf area (Table 1); leaf area and leaf chlorophyll content (Table 2); leaf N, P, K, Ca and B content (Table 3); nodes and leaf total and reducing sugars (Table 4); total indoles content (Table 5); percentage of fruit set and retained fruits and total fruit yield/tree (Table 6); and fruit weight, size (Table 7); polar and equatorial diameters, and SSC (Table 8) in the two studied seasons, except leaf chlorophyll content in which this treatment was in the top ranking position in 2006 and the 2nd ranking in 2005. This treatment, i.e., 80 g B + 160 g Ca resulted also in the lowest significant values of spur leaf chlorophyll content in 2006 (Table 2), fruit firmness in the two studied seasons (Table 7), and leaf phenol content in 2006 (Table 5). Meanwhile, the control treatment resulted in the largest significant values of nodes and leaf total phenols content (Table 5) and fruit TA (Table 8); and in the least significant values of leaf N, P, Ca, and B content (Table 3); number of spur leaves, spur leaf area and total spur leaf area (Table 1); leaf area and leaf chlorophyll content (Table 2); leaf reducing sugar content (Table 4); leaf total indoles content (Table 5); percentages of fruit set and retained fruits and total fruit yield/tree (Table 6); and fruit weight, size (Table 7), polar and equatorial diameters, and SSC (Table 8) in the two studied seasons. Additionally, the control treatment resulted in the lowest values of nodes reducing sugars content in 2005 (Table 4) and spur leaf chlorophyll content (Table 2), leaf Ca content (Table 3), and nodes total sugars content in 2006 (Table 4).

The general trend in most characters measured was that the 80 g B + 160 g Ca soil treatment was followed by the 16 g B + 32 g Ca foliar treatment and then by the 8 g B + 16 g foliar Ca with or, sometimes, without significant differences. These three treatments were followed in most characters measured by the 8 and 16 g B foliar treatment. The 16 g and 32 g foliar Ca treatments occupied in most characters measured, a position next to the control with or, sometimes, without significant differences from the control and/or the other foliar B treatments.

These results are in harmony with the well-known role of B and its interaction with Ca in plants. According the classical work of Gauch and Dugger (1953), B reacts which sugar to form an ionizable sugar-borate complex which moves through cellular membranes more readily than non-borated, non-ionized sugar molecules. They suggested that B deficiency symptoms are an expression of sugar deficiency in the cambia, stem tips, root tips, and flowers or fruits.

Transfer of sunflower (*Helianthus annus* L. cv. Russian Mammoth) seedlings from complete nutrient solution to solutions deficient in either boron or calcium resulted in a steady decline in the rate of indole-3-acetic acid transport, compared to transport in seedlings that remained in the complete solution. In seedlings transferred to solutions deficient in both B and Ca, the decline in auxin transport was greater than in seedlings deficient in only one element. The transfer of B- or Ca-deficient seedlings back to the complete solution prevented further decline in auxin transport, but auxin transport did not increase to the same level as in seedlings maintained in complete solution (Tang and dela Fuente, 1986a).

According to Matoh and Kobayashi (1998), B and Ca are essential inorganic constituents of pectic polysaccharides in higher plant cell walls.

Both B and Ca are essential for membrane integrity (Tang and dela Fuente, 1986b) and are considered essential inorganic constituents of pectic polysaccharides in plant cell walls (Matoh and Kobayashi, 1998).

The present results are also in harmony with former findings regarding boron's role in improving fruit set (Callen *et al.*, 1978; Chaplan *et al.*, 1977; Hanson *et al.*, 1985; Hanson, 1991; Kabeel *et al.*, 1999; Nyomora *et al.*, 1999; Wojcik and Wojcik, 2003; Wojcik, 2006; Wojcik and Treder, 2006), yield (Chaplin *et al.*, 1977; Stover *et al.*, 1999; Kabeel *et al.*, 1999; Wojcik and Wojcik, 2003; Wojcik and Treder, 2006), fruit quality attributes, viz., SSC, weight, and volume (Kabeel *et al.*, 1999), and leaf B content (Kabeel *et al.*, 1999; Peryea *et al.*, 2003; Wojcik and Wojcik, 2003; Wojcik and Treder, 2006) and its functions in indole and phenol metabolism (Blevins and Lukaszewski, 1998).

The reported Ca role in pollen germination and pollen tube growth (Brewbaker and Kwach, 1963) was reflected, in this study, in improving fruit set. Our results also confirm those of Rease and Drake (1995) and Gerasapoulos and Richardson (1997) concerning the positive effective of Ca sprays in increasing pear yield and flesh firmness, respectively.

In conclusion, it is recommended for pear growers in sandy soil to apply 80 g boric acid (17% B) and 160 g chelated Ca (12% Ca)/tree to the soil three times at stages of bud swelling, 70% flowering, and when fruit reaches the hazelnut-size for the improvement of yield and fruit quality.

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# تأثير المعاملة بالبورون والكالسيوم علي محصول وجودة ثمار الكمثرى الليكونت

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## الملخص العربي

أجريت هذه الدراسة خلال عامي ٢٠٠٥ و ٢٠٠٦ لتقييم استجابة أشجار الكمثرى (بيرس كميونس) الليكونت النامية في أرض رملية لمعاملتي رش النموات الخضرية وأرضياً في التربة بكل من البورون والكالسيوم. أجريت المعاملة بحامض البوريك (بورون) والكالسيوم المخلبي (كالسيوم) بمعدل ٨ أو ١٦جم بورون رشاً ، و١٦ أو ٣٢جم كالسيوم رشاً ، و ٨جم بورون + ١٦جم كالسيوم رشاً ، ١٦جم بورون + ٣٢جم كالسيوم رشاً و ٨٠جم بورون + ١٦٠جم كالسيوم بطريقة الإضافة إلى التربة في تجربة بتصميم القطاعات العشوائية الكاملة لم تعامل فيها أشجار الكنترول بأي من البورون أو الكالسيوم. تكرر إجراء المعاملات ثلاث مرات خلال مراحل إنتفاخ البراعم ، وعند ٧٠% إزهار ، وعندما بلغت الثمار حجم البندقة.

سجلت النتائج على عدد الأوراق الدابرية ومساحة الورقة الدابرية الواحدة ومساحتها الإجمالية ، ومساحة الورقة ، والمحتوى الكلوروفيلي لكل من الأوراق والأوراق الدابرية ، ومحتوى الأوراق من عناصر النيتروجين والفوسفور والبوتاسيوم والكالسيوم والبورون ، ومحتوي كل من العقد والأوراق من السكريات الكلية والسكريات المختزلة والإندولات الكلية والفينولات الكلية ، ونسبتي العقد والثمار المتبقية ، والمحصول الكلي ، وصفات الثمار : الوزن والحجم والصلابة والقطران القطبي والاستوائي ومحتوى المواد الصلبة الذائبة والحموضة المعايرة.

كانت استجابة معظم الصفات المدروسة لمختلف المعاملات على درجة عالية من التجانس. وبينما أعطت المعاملة ٨٠ جم حامض بوريك + ١٦٠ جم كالسيوم مخلبي عن طريق التربة أقل محتوى من الكلوروفيل بالأوراق الدابرية في ٢٠٠٦ ، وأقل صلابة للثمار في موسمي

الدراسة ، فإن تلك المعاملة أعطت أعلى استجابة جوهرية في معظم الصفات الأخرى في عامي الدراسة ، متضمنة : عدد الأوراق الدابرية ومساحة الورقة الدابرية ومساحتها الإجمالية ، ومساحة الورقة ومحتوى الأوراق من الكلوروفيل ومحتوى الأوراق من النيتروجين والفوسفور والكالسيوم والبورون ، ومحتوى العقد والأوراق من السكريات الكلية والمختزلة والإندولات الكلية ، ونسبتا عقد الثمار والثمار المتبقية ، ووزن الثمرة وحجمها وقطراها القطبي والاستوائي ومحتواها من المواد الصلبة الذائبة. أما معاملة الكنترول فإنها أعطت نتائج معاكسة تماماً لمعاملة ٨٠ جم بورون + ١٦٠ جم كالسيوم أرضياً في معظم الصفات التي ذكرت أعلاه ، بالإضافة إلى أنها أعطت أعلى قيم جوهرية لكل من محتوى العقد والأوراق من الفينولات الكلية ومحتوى الثمار من الحموضة المعايرة. وكاتجاه عام .. فإن معاملة ٨٠ جم بورون + ١٦٠ جم كالسيوم أرضياً أعطت أفضل النتائج ، وتلتها في التأثير معاملة ١٦ جم بورون + ٣٢ جم كالسيوم ، ثم معاملة ٨ جم بورون + ١٦ جم كالسيوم رشاً. وكانت هذه المعاملات الثلاث متبوعة غالباً بمعاملتي ٨ ، ١٦ جم بورون رشاً . أما معاملتي الـ ١٦ ، ٣٢ جم كالسيوم رشاً فقد احتلتا – في معظم الصفات – موقعاً بين معاملات البورون بالرش ومعاملة الكنترول. ولقد أوصي بمعاملة أشجار الكمثرى – أرضياً – بمعدل ٨٠ جم حامض بوريك + ١٦٠ جم كالسيوم مخلبي ثلاث مرات خلال مراحل انتفاخ البراعم ، وعند ٧٠% إزهار ، وعند وصول الثمار حجم البندقة ، وذلك لأجل زيادة المحصول وتحسين جودة الثمار.