Effect of Bending Date on Spurs Formation and Fruit Set of Le-Conte Pear Trees

Hanaa M. Sherif

Horticulture Research Institute, Agriculture Research Center, Egypt.
Hanaa.sheref@yahoo.com

Abstract: This investigation was carried out during 2009/2010 and 2010/ 2011seasons on four- years- old "Le - Conte" Pear trees (*Pyrus communis)* budded on *Pyrus betulaefolia* rootstock and grown in a sandy soil in El-Khattaba at El-Monufia Governorate to study the effect of bending dates on spurs formation, fruit set and fruit quality of Le-Conte trees. Bending occurred on three stages: (i) early summer (June &July), (ii) summer (August) and (iii) late summer (September & October).Degree of bending was 90 C^{o} on branches of two years old. Bending increased number of current shoots; vegetative spurs, flowering spurs, and fruit set. Results revealed that all treatments significantly increased yield, fruit weight, fruit size, fruit length, fruit diameter, in both seasons. Carbohydrates content of spur terminal buds of shoots increased by bending date. Contrarily, nitrogen decreased, consequently carbohydrates / nitrogen content increased by bending date. Generally, the best date for bending "Le-Conte" pear trees was in late summer (September) followed by early summer (July).
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1. Introduction

Pear (*Pyrus communis*) is a popular fruit in temperate regions and one of the most important deciduous fruits in Egypt. Alexandria, Behera and Monufia Governorates are considered the most productive areas of pear. Bending has been proposed as alternative pruning for promoting early fruit production and controlling tree size (Lauri and Lespinasse, 2001).

Flower buds of pear are formed on terminal shoots and short spurs of 2years - old. Flower bud development can be altered by many factors and practices (Bahlool *et al.,* 2000). Bending affects on light penetration in the tree inner canopy and sunlight distribution influencing flower initiation, fruit set and fruit quality, particularly size and soluble solids content depending on seasonal sunlight availability (George *et al.,* 1996 and Kattab *et al.,* 2002).

Pear production is closely affected by cultural practices on flower bud formation, fruit set and yield. Colaric *et al,*. (2007) suggested that these variations of 'Conference' fruit subjected to different bending treatments due to effect bending alone, but may be indirectly affected by other physiological responses of the fruit tree. Whatever, it seems that variations are affected by bending time. Costes *et al.* (2006) mentioned that bending time is necessary to regulate excessive vegetative growth and increase flowering and fruiting. It has been approved that branch bending was the most successful traditional method from the applied cultural practices in controlling growth and fruiting.

Moreover, Lauri and Lespinasse (2001) have shown that the tree's reaction to bending also varies with the genotype and the time of bending as well as with the angle of bending, the duration of bending time. In this regard, Bahlool *et al.* (2000) studied the effected of some cultural practices such as shoot bending, tip pruning,shoot bending &tip pruning, defoliation,shoot bending& defoliation, tip pruning& defoliation,shoot bending &tip pruning& defoliation and girdging the limbs with 9mm width on flower bud formation, fruit set and yield of "Le-Conte "pear trees. Those treatments caused in an increase in spur percentage, fruit set and yield.

Shoot bending may be enhance flowering of young trees, encourage the development of flower buds and increase yield in pear trees (Lin *et al.,* 1990 and Chan Chung *et al.,* 1997).In light of the positive findings for bending, Lawes *et al.* (1997) reported that bending resulted in higher floral precocity and in reduced shoot vigor of the "Doyenne ducomice "pear. Apple and Pear trees yielded more fruit and produced earlier fruit if regulated only by bending than those regulated by pruning alone (Goldschmidt-Reischel, 1997). It is clear that shoot bending treatments also caused rapid increase in the number of nods in the auxiliary buds in Japanese pear (*Pyrus serotina Rehd*) and the final percentage of flower bud formation in the control only reached 15.2% compared with approximately 60% for the treated shoots (Banno *et al.,* 1985).

Other studies have indicated that the highest concentrations of carbohydrate reveres necessarily result in more flowering, fruit set and yield.

However, the correlation between flower bud density and vegetative growth may be on apical dominance phenomenon, thus substances other than carbohydrates (Maust and Darnell 2000).

Summer bending (June-July during flower primordial initiation) promotes lateral growth and reduces fruit number and weight. While winter bending might be a good compromise to reduce lateral growth, distributing it along the shoot, to maintain good fruiting potential (Pierre, 2001). Herein, Ito *et al.*(2004) studied carbohydrate metabolism in the lateral buds and in the shoot internodes of Japanese pear. They observed that bending influenced higher contents of sorbitol and sucrose in the central internodes of the bent branch in comparison to that of the control (the vertical branch).

The aim of this study was to show the necessity of regulating excessive vegetative growth and increasing flowering and fruiting which reflect to good economic return. Therefore, this study was under taken to evaluate the prospective effects of different dates on branch bending to maintain the best and optimal date for increasing yield and improving fruit quality of 'Le-Conte' Pear trees.

2.Material and Methods

This study was conducted during two consecutive seasons (9009/2010 & 2010/2011) on 4 years old "Le-Conte" pear trees (*Pyrus Communis*.L) budded on *Pyrus betulaefolia* pear rootstock and grown at El- Khataba Village at El-Monufia Governorate. Selected trees were grown in sandy soil, at 5× 5m apart, nearly similar in growth vigor and fruiting, free from any visual infections and received regularly the recommended horticultural practices.

Four different management treatments were applied to the trees, and each single treatment was repeated randomly on nine trees to evaluate the best date for bending Le-Conte shoots. In both seasons (2009/2010 and 2010/2011), treatments were carried out on 4-year old trees.

Treatments were made on two years old branches as follows:

(i)Early summer treatment (June& July).

(ii) Summer treatment (August).

(iii)Late summer treatments (September and October months). Where 2-year- old branch per tree (on the four direction and comparable properties) was bent to an angle 90^{o} from the vertical position in (September&October2009).

(iv)Trees without bending (Control: labeled branches were not bent but remained at 45^{o} from the vertical).In second (2010) season the same treatments were carried out on the same branches. Before bending, the bent branches (2-years old) were grown like the control branches at an angle of 45^{o} from the vertical position. All bent branches, as well control branches, were allowed to develop without pruning from 2009 to 2011.The treatments were arranged in a completely randomized design. Each treatment was replicated three times and each replicate was re

Furthermore, to evaluate the efficiency of the tested treatments on tree fruiting and fruit quality the following measurements were carried out.

1-Vegetative Growth Measurements:-

a) Average number of current shoots were counted on August in both seasons.

b) Average number of vegetative spurs (%) were calculated on August for both seasons.

2- Spurs mineral content: -

Samples of ten spurs from the middle part of shoots were selected at random from each replicate (after harvest) to determine their content of N, C. using the kjeldahl digestion method for N as described by A.O.A.C (1995), and the colorimetric method for total carbohydrates (%) as outlined by Dobois *et al.*, (1956). Spurs content of nutrients were determined as basis of dry weight.

3-Tree fruiting:

a) Average number of flowering spurs (%).

b) Fruit set percentage:-

Total number of flowers at full bloom stage was counted on the bended shoots. After month, number of fruits were computed to calculate fruit setting (on May), and before harvests the yield number of fruits were counted to calculate final fruit setting (on July).

c) Yield: - At harvest time (maturity) in both seasons yield of selected trees was determined as Kg/tree for all treatments.

d) Fruit quality: - Fruit samples were collected fruits were harvest from those branches (three represented fruit from each branch, repeated on three trees per treatment) at commercial maturity on August 2010 and 2011, for determining fruit characteristics.

4- Physical properties and chemical fruit characteristics:-

a- Fruit physical properties i-e fruit weight (g), size (cm^3), length (cm), diameter (cm), and firmness (g /cm^2) using lFRA Texture analyser on 5 ml inside the fruit skin by constant speed 2ml/sec. were determined and recorded.

b- Fruit chemical properties i-e total soluble solids (%), total sugar (%) and juice acidity (%) were determined according to A.O.A.C (1995).

Data were statistically analyzed according to the method of Sendecor and Cochran (1990) in each L.S.D at 5% level for comparison between means of each treatment

3. Results and Discussion

Vegetative Growth:-

1-Average number of current shoots:-

Referring the specific effect of branch bending, it was quite evident as shown in Table (1) that all dates of branch bending effected the significant increase in number of current shoots compared with un- branch bending (control) during 2009/2010 and 2010/2011 seasons. The greatest increase was realized as a result of shoot bending in July (9.00 & 13.67 cm) followed by that in June (6.00 & 8.33 cm) and August (6.00 & 9.00cm). Branch bending in October recorded the least increase in number of shoots (4.00&5.33 cm). Those results are in agreement with Bahlool *et al.* (2000) and Colarric *et al.* (2007) who mentioned that shoot bending resulted in greatest total branch length.

2-Average number of vegetative spurs (%):-

Obtained data during both 2009/2010 and 2010/2011 experimental seasons regarding the response of number of vegetative spurs (%) in Le-Conte pear trees to specific effect of branch bending are tabulated in Table (1).It is clear that all branch bending increased significantly the percentage of vegetative spurs during the two seasons under study. However, bending gave the highest increase in No. of vegetative spurs in July (13.33%) in first season and (22.335) in June in the second one. Whatever, bending in October gave the least number of spurs compared with the other dates and control. Decrease in number of vegetative spurs was previously reported as a resulted of shoot bending by Bahlool *et al.* (2000) who reported that more nodes and leaves per shoots were formed as result of shoot growth reduction.

Table (1) Effect of bending date on number of current shoots and percentage of vegetative spurs of" Le-Conte" pear trees in both (2009\2010) and (2010/2011 seasons

Treatments	Bending date	No. of current shoots		Vegetative spurs (%)	
		2009/2010	2010/2011	2009/2010	2010/2011
Early summer	June	6.00 b	8.33 b	12.00 b	22.33 a
	July	9.00 a	13.67 a	13.33 a	19.33 b
Summer	August	6.00 b	9.00 b	3.33 d	7.67 d
Late summer	September	6.00 b	8.33 b	3.33 d	7.67 d
	October	4.00 c	5.33 c	1.67 e	4.33 e
Without bending		2.67 d	3.67 d	10.00 c	14.33 c

Means within each column followed by the same letter(s) are not significantly different at 5% level

Mineral spurs content:-

Bending shoots and branches had changed the natural gradients of carbohydrate concentration and coefficients of polarity, increased the sugar content and promoted a more uniform carbohydrate distribution along the horizontal and the bended branches. Table (2) shows the effect of branch bending on "Le-Conte" pear trees during the two experimental seasons (2009/2010 and 2010/2011). It is noticed that bending shoots in late summer (September &October) gave the highest values from carbohydrates in both seasons 2009/2010 and 2010/2011followed by summer (August) and early summer (June &July) compared with the control. Meanwhile, nitrogen content decreased in versa with carbohydrates. Herein, C/N ratio increased in the same trend with carbohydrate. Our data are in a line with Maust and Darnell (2000) who showed that the correlation between flower bud density and vegetative growth may be due to an apical dominance phenomenon, thus substance other than carbohydrates (e.g., hormones) may play a role in spurs information.

Table (2) Effect of bending date on C(%),N(%) and C/N ratio of spur "Le-Conte" pear trees in (2009\2010) and (2010/2011) seasons.

Treatments	Bending date	C (%)		N (%)		C/N ratio	
		2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011
Early summer	June	27.42… b	28.32 c	1.80 a	1.75 a	15.23 e	15.67 e
	July	31.69 a	33.38 ab	0.87 c	0.89 c	36.42 c	35.61 c
Summer	August	30.68 ab	30.68 bc	0.93 c	0.92 c	33.19 d	33.35 d
Late summer	September	34.43 a	35.86 a	0.85 c	0.85 c	40.51 a	40.51 a
	October	33.67 a	33.88 ab	0.89 c	0.89 c	37.83 b	37.83 b
Without bending		20.10 c	20.92 d	1.60 b	1.56 b	12.56 f	12.88 f

Means within each column followed by the same letter(s) are not significantly different at 5%

Flowering growth:-

Percentage of flowering spurs:-

Concerning the effect of branch bending during 2009/2010 and 2010/2011 seasons regarding the effect of bending on percentage of flower buds in Le-Conte pear trees are presented in Table (3).It was noticed that all bending dates gave a significant increase in percentage of flower spurs than in the control. Number of flower spurs increased significantly in September followed by July, October, August and June (51.67, 50.67, 48.33, 38.00 and 31.00%, respectively) compared with the control (19.33%) in the first season. In the second season the highest percentages were realized as a result of bending date in October followed by July, September, August and June (95.33, 90.67, 90.00, 81.33 and 70.0%, respectively) compared with the control (22.0%).Those increments due to the lowest number of vegetative spurs may be due to change in flowering spurs in 2nd season and the accumulated of carbohydrates in the central internodes of the bent branches in comparison to the control. These findings are in harmony with Chan -Chung *et al.* (1997), Bahlool *et al.* (2000) and Ito *et al.* (2003) in their studies on pears.

2- Fruit set (%):-

Percentage of fruit set affected by date of bending during the two successive seasons of 2009/2010 and 2010/2011 are recorded in Table (3).There is a significant increase in fruit set as a result of bending branches in the two studied seasons Bending shoots gave the highest percentage of fruit set in both seasons compared with the control. It is cleared that the highest fruit set (%) from bending treatments was in July (10.42 &33.52%) followed by June (7.76 & 20.82%), September (6.36 & 20.53%), August (5.88 & 17.33%), and October (5.18&9.75%) compared with the vertical branches in both seasons under study. It is obvious that fruit set% reflects the increase in number of flowering spur percentage. Our data are in harmony with Lin *et al.* (1990), George *et al.,* 1996, Chan-Chung *et al.* (1997), Bahlool *et al.* (2000) and lauri and lespinasse (2001)who mentioned that bending branches increased fruit set during their studies on pear.

Table(3) Effect of bending date on percentage of flower spurs, fruit set and fruit yield of Le-Conte pear trees in (2009\2010) and (2101/2011) seasons.

Treatments	Bending Date	No. of flower spurs (%)		Fruit set (%)		Fruit yield(kgs)	
		2009/2010	2010/2011	2009/2010	2010//2011	2009/2010	2010/2011
Early summer	June	31.00 c	70.00 c	7.76 b	20.82 a	3.61 c	8.18 b
	July	50.67 a	90.67 a	10.42 a	22.52a	6.23 a	12.63 a
Summer		38.00 b	81.33 b	5.88 c	17.33 b	4.40 b	12.24 a
Late summer	September	51.67 a	90.00 a	6.36c	20.53 a	6.19 a	4.43 c
	October	48.33 a	95.33 a	5.18c	9.75c	3.50 c	7.13 b
Without bending		19.33 d	22.00 d	1.30 d	2.67 d	0.81 d	2.04 d

Means within each column followed by the same letter(s) are not significantly different at 5% level.

Tree yield:-

Table (3) displays clearly that productivity of pear trees (expressed as harvest fruits in Kgs/tree) were influenced significantly by branch bending in the two seasons (2009/2010 and2010/2011) under study. It is cleared that all dates of bending increased significantly yield per tree of Le-Conte pear trees during 2009/2010 and 2010/2011seasons. The best results were attained as a result of bending branches in July and August followed by the other dates compared with the control. These results are in line with those of Lin *et al.*(1990),Chan-Chung *et al.* (1997) and Bahlool *et al.* (2000) in their studies on pears.

Physical and chemical properties of fruits:-

(A)Physical properties:-

Average fruit weight (g), size (ml.^{3}), dimensions (equatorial &polar diameters in cm) and firmness were investigated in response to branch bending. Recorded data during seasons2009/2010 and 2010/2011 experimental seasons are tabulated in Tables (4) and (5).

1- Average fruit weight and size:-

Obtained data in Table (4) revealed that all dates of bending significantly increased fruit weight (g) and size (ml^3) compared with control trees. The best date for branch bending in this respect were in June (169.00 g & 170.83 ml) followed by October and September in 1st season and in September (212.13g&206.67ml) followed by June, August and October in the second one. Moreover, the least number was resulted from branches being bended in July (119.57& 153.27 g and 119.17&142.50 ml^3) compared with the all dates of bending and control. These results are in harmony with Bahlool *et al.* (2000), Li-Tain *et al.* (1996) on pear and Pierre, (2001) on apple. That bending increased the number, as well as fruit weight during their studies on pear and apple.

Table (4) Effect of bending date on fruit weight (g) and fruit size (ml3) of" Le-Conte' pear trees in (2009 \ 2010) and (2010 / 2011) seasons.

Treatments	Bending Date	Fruit weight (g)		Fruit size (ml^3)	
		2009/2010	2010/2011	2009/2010	2010//2011
Early summer	June	169.00 a	180.83 b	170.83 a	175.00 b
	July	119.57 e	153.27 d	119.17 e	142.50 c
Summer	August	133.03 d	176.90 c	124.17de	169.17 b
Late summer	September	142.77 c	212.13 a	141.27 c	206.67 a
	October	161.17 b	174.77 c	151.67 b	172.83 b
Without bending		129.10 d	151.47 d	125.40 d	146.13 c

Means within each column followed by the same letter(s) are not significantly different at 5% level.

2-Fruit dimensions (equatorial & polar diameters):-

Data in Table (5) clearly show the effect of branch bending on the fruit dimensions (equatorial &polar diameters in cm) of 'Le-Conte' pear fruit. It is quite clear that results reflect the same trend of response previously detected with fruit weight and size. Anyhow, branch bending increased significantly fruit dimensions, but differences between dates of bending were less pronounced. Branch bending in September gave the highest fruit width and height compared with the control.Similar results concerning the effect of branch bending are agree with those obtained by Bahlool *et al.* (2000), Li-Tain *et al.* (1996) in their studies on pear.

Fruit firmness (g/cm^2):-

Data in Table (5) showed that the differences in fruit firmness were significant in both seasons under study (2009\2010 and 2101/2011). The highest values were obtained as a result of branch bending in September followed by August and July. Meanwhile, the least values were noticed as a result of bending in October.

Table (5) Effect of bending date on fruit polar diameter (cm), fruit equatorial diameter width cm) and fruit firmness ($Ib/Inch^2$) of "Le-Conte' pear trees in (2009\2010) and (2101 /2011) seasons.

Treatments	Bending Date	Fruit polar diameter (cm)		Fruit equatorial diameter (cm)		Fruit firmness (g/cm^2)	
		2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011
Early summer	June	8.20 ab	8.40 b	6.07ab	6.63 b	189.50 d	197.33 cd
	July	7.67 bc	8.03 c	5.97 b	6.00 c	191.83 c	200.50 c
Summer	August	7.63 bcd	7.63 d	5.97 b	6.53 b	205.67 b	208.77 b
Late summer	September	8.67 a	8.93 a	6.30 a	7.10 a	254.50 a	256.33 a
	October	7.47 cd	8.60 b	6.27ab	6.67 b	177.33 e	181.27 e
Without bending		7.00 d	6.60 e	6.07ab	6.03 c	189.00 d	197.00 d

Means within each column followed by the same letter(s) are not significantly different at 5% level.

B-Chemical properties:-

1- Total soluble solids:-

Regarding the effect of branch bending on total soluble solids Table 6 showed that the increase in T.S.S percentage was obtained by branch bending in September as compared with untreated trees in the both seasons (2009/2010 & 2010/2011). Such results are in agreement with George *et al.*(1996) who cleared that sunlight distribution influence flower initiation, fruit set and fruit quality, particularly size, color and soluble solids content,depending on the seasonal trend of sunlight availability.

2-Acidity

It is obvious that in both seasons (2009/2010 & 2010/2011) branch bending showed nearly insignificant effect on fruit acidity with the control. Branch bending in August gave highest percent of acidity in the 2nd season (Table 6).

3- T.S.S/acid ratio:-

Table (6) shows that branch bending in June gave less values in T.S.S/ acid ratio than the other treatments including the control in 2009/2010 & 2010/2011 seasons. Branch bending in July gave high value in T.S.S./acid ratio compared with the other treatments in both seasons under study. That is due to the raise in fruit acidity percent produced by these treatments in both seasons.

Table (6) Effect of bending date on chemical characters of" Le-Conte" pear trees in both (2009/2010) and (2010 /2011) seasons.

Treatments	Bending Date	T.S.S (%)		Acidity (%)		T.S.S/ Acidity	
		2009/2010	2010/2011	2009/2010	2010/2011	20092010	2010/2011
Early summer	June	13.40 c	12.83 b	0.47 ab	0.500 ab	29.00 d	25.67 c
	July	14.533ab	14.16 a	0.33 c	0.37 c	44.45 a	39.31 a
Summer	August	14.17 b	13.83 a	0.47 ab	0.53 a	30.72 cd	26.17 c
Late summer	September	14.87 a	14.00 a	0.37 bc	0.40 c	41.17ab	35.00 ab
	October	14.50 ab	14.17 a	0.37 bc	0.43 bc	40.31 abc	33.08 b
Without bending		12.50 d	12.33 b	0.500 a	0.433 bc	32.03 bcd	25.10 c

Means within each column followed by the same letter(s) are not significantly different at 5% level.

Finally, it can be concluded that branch bending is more practical and has positive effect on yield and fruit quality. Referring to the present results, it could be concluded that branch bending of "Le-Conte" pear trees grown on sandy soil in September enhance tree yield and fruit quality.

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