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# Effect of Heading Cut Levels, Bending and NAA on Spurs Formation, Yield and Fruit Quality of Sun Gold Plum Cultivar

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**Abstract:** This study was carried out during two successive seasons of 2008/2009 and 2009/2010 on 6 years old Sun Gold plum trees budded on Mariana rootstock. Trees were grown in sandy soil of a private orchard at Markaz-Badr region, El-Behera Governorate, Egypt. Four heading cut levels treatments were applied in winter i.e. tipping, shortening 1/3, 1/2 of branches' length and control (un pollarded) trees with or without some spring and summer applications i.e., NAA at 150 ppm, shoots bending and combination between them. Concerning the effect of heading cut levels on number of spurs/shoot; tipping cut treatment was more effective in this concern than either shortening cut treatments or control trees. Moreover, the combination between spraying of NAA plus shoot bending application gave the highest spurs/shoot, followed by treatment of bending and spraying NAA. In addition, Tipping with NAA + bending treatment gave the highest spurs values (10.16 and 10.45 spurs/shoot) in the first and second seasons, respectively. Distribution of spurs at shoot parts was affected by all treatments and higher the terminal or middle parts than the basal part of shoot in the two seasons under study. Whereas, the optimize C/N ratio, yield and fruit quality (weight, size, length, diameter, shape, flesh thickness, TSS and acidity of the fruits) were obtained by shortening the branches by 1/3 level with NAA plus bending treatment in both seasons.

**Key words:** Binding · C/N ratio · Fruit quality · Heading cut · NAA · Plum · Sun Gold · Spurs · Tipping and Yield

## INTRODUCTION

Several techniques are used to reduce or maintain tree canopy size, toping uses heading cuts through wood more than several years old to shorten all stems and branches [1]. Whereas, pollarding time remained the same for each subsequent year, longitudinal sections through stems showed that barrier zones and decay extended farther behind heading cuts on topped trees five years after the initial pruning than cuts on pollarded trees [2]. Heading cuts through branches up to about three years old and annually removes all or most sprouts back to the original heading cuts [3]. Therefore, pruning has been practiced for ages in controlling tree size because it has much less stimulating effect shoot re-growth [4]. Heading back 1/3 of shoots length gave more yield of fruits than heading back 2/3 of them [5].

According to actual knowledge that stated by many workers, summer pruning is more effective in reducing tree size than dormant pruning, because promotes the growth of short shoots able to fruiting [6]. On the other side, successful plum production in the competitive modern market requires from polish growers optimizing yield, fruit quality; and improving production efficiency, pruning has generally a dwarfing affection the whole tree [7], but just when dormant pruning results in greater shoot re-growth than summer pruning on plum trees [8]. Whereas, Flore *et al*. [9] noticed higher yield and better fruit quality of plum trees after pruning compare with control trees. Also, the plum cultivars have very different characters; some cultivars tend to will balanced yields and other shows on average of too high or low yields. In general, pruning treatments had increased tree yield (up to 53%) compared to unpruned check. Also, pruning plum tree during the late December was found to be optimum as indicated by higher yield than pruning in late January [5]. In addition, summer branch bending is a long established and widely used cultural practice in orchards and its concept has, nowadays, been integrated in to the training system [10]. Lawes *et al*. [11] reported that bending resulted in higher floral precocity and in reduced shoot vigor of the

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Doyenne du comice pear. Apple and pear trees yielded more fruit and produced fruit earlier if regulated only by bending than those regulated by pruning alone [12]. However, Lauri and lespinasse [13] have shown that the trees reaction to bending also varies with genotype and time of bending, as will as with the branches angle degree of bending.

To determine if differences in the pruning and training system adopted could modify the concentration of C and N reserves in trees, *prunus domestica* was pruned and trained in two different ways of vertical and horizontal branches systems, horizontal branches (bending) system gave the higher C/N ratio in wood tissues than vertical system [14]. Moreover, bending shoots to horizontal position is known to slow down shoot growth [15, 16]. Similarly, summer bending increased spurs formations on shoots [17-19].

The plum cultivars have very different characters, some cultivars tend to well balanced yields and other shows on average of too high or low yields and important for producing quality is an optimal fruit set [20]. Zbigniew [21] found no difference in flower initiation in shoots of Japanese plum trees, which were summer pruned with various severities. It is known that some prune cultivars set floral buds simultaneously on both spurs and long shoots, while the others do on either spurs or long one-year-old shoots [22]. Therefore, stimulation of shoot growth in plum by dormant tipping is not always associated with a decrease in floral bud induction and spur formation because it may be cultivar growth habit related [23]. In addition, Aleksander and Kazimierz [24] reported that in all three years at the experiment, an increasing in the intensity of ethylene evaluation by plum flowers and fruitlets was observed after NAA application. An additional indicator of the treatment at the time was falling of petals and a distinctly visible abscission zone between the floral tube and the pedicle, the distinctly more intensive ethylene evaluation was maintained for about eight days after the treatment.

The aim, of this study, is to evaluate spurs formation, yield and fruit quality of Sun Gold plum cultivar under the effect of winter heading cut levels with spring spraying of NAA and/or summer bending applications.

## MATERIALS AND METHODS

This study was carried out during two successive seasons of 2008/2009 and 2009/2010 on 6 years old trees of Sun Gold plum cultivar (newly imported from South Africa) budded on Mariana rootstock (Fig. 1).

Fig. 1: The tree and fruits of Sun Gold plum cultivar grown in a private orchard at Markaz Badr district, El-Behera Governorate, Egypt.

The trees were grown in sandy soil at private orchard, in Markaz Badr district at El-Behera Governorate, Egypt. They were spaced 5×5 m apart, trained as open center shape system and irrigated by drip irrigation system, as well as, subjected to the recommended agriculture practices. This study conducted forty-eight similar trees in shape vigor and uniform of growth. All trees were sprayed with hydrogen cyanamid (commercial product of Dormex contained 49% $H_2CN_2$) at 1.5% on 20$^{th}$ January in both seasons. Four winter heading cut levels treatments were applied from terminal branch on (one year old shoot) 15$^{th}$ December i.e., tipping 0.5-1 cm, shortening 1/3 and 1/2 branches length beside control trees (un pollarding). All previous winter pruning were applied with or without the following spring and summer applications i.e., double spraying of 150 ppm NAA (15$^{th}$ March, 70% full bloom and 1$^{st}$ April, after initial fruit set), bending at 45 angle degree from the vertical axe on the 1$^{st}$ week of July and combination between them. Each treatment contained three replicates (trees).

The following parameters were estimated and recoded as follows:

- Numbers of spurs that formed on each selected branch (9 branches on each replicate), as well as, their distribution on the branch length (terminal, middle and basal) were determined at the end of growing season (15$^{th}$ December).
- C/N ratio: Samples of buds and nodal tissues were taken monthly from the 2$^{nd}$ week of September until January and dried to determine the total nitrogen, according to Pregel [25] and total carbohydrates as described in AOAC [26] and C/N ratio was calculated.
- Yield and fruit physical characteristics: The yield was estimated (kg/tree) after fruits harvested at maturity stage (during the 2$^{nd}$ week of Augusts). 10 fruits of each replicate were used to determine the fruit physical characters i.e., fruit weight (g), fruit volume ($cm^3$), fruit length (cm), fruit diameter (cm), flesh thickness (cm) and flesh firmness ($Lb/inch^2$, by using pentameter pressure tester).
- Fruit chemical characteristics: 10 fruits of each replicate were used to determine the total soluble solids (TSS %) and fruit acidity (%) by titration as malic acid as described in AOAC [26].

**Statistical Analysis:** The obtained data were tabulated and statistically factorial analyzed as randomize complete block design. The means of results were compared using LSD method at 5% level [27]. The percentages were transformed to arcsine to find the binomial percentages according to Steel and Torrie [28].

## RESULTS AND DISCUSSION

### Spur Formation

**Total Number of Spurs/Branch:** Data presented in Table 1 show that all pruning treatments significantly increased the number of spurs formed per branch. Concerning the effect of heading cut levels factor, tipping cut treatment was more effective in this concern (8.38 spurs/branch) than either shortening cut treatments 1/3 and 1/2 branches (7.65 and 5.81 spurs/branch) respectively. Nevertheless, control trees (un pollarded) gave the lowest spurs/branch (4.61 spurs/branch). Moreover, the effect of spring and summer applications, appeared that combination between NAA + bending gave the highest results in this concern (8.54 spurs/branch) followed by bending alone (7.29 spurs/shoot) or NAA alone (5.68 spurs/branch) then plum trees without any spring and summer applications (4.95 spurs/branch). In addition, the 2$^{nd}$ season was more effective than the first one under study.

Concerning, the interaction between three factors, heading cut levels, spring and summer applications and seasons, tipping with NAA + bending gave the highest results (10.16 and 10.45 spurs/branch) in the 1$^{st}$ and 2$^{nd}$ seasons, respectively, compared to other treatments under study.

These results agreed with Edward *et al*. [5] on plum tree and Savoboda [29], Ebied [30] and Mohamed *et al.* [19] on different apricot cultivars. Also, Towfik *et al*. [31] noticed that heading cuts of current season shoots gave the higher number of spurs than pinching. Ferree and Schmid [32] added that bending vigorous laterals resulted in more flowering spurs than heading on the apple trees.

**Distribution of Spurs at Different Branch Parts:** Distribution of spurs, at different branch parts (basal, middle and terminal) was significantly affected by all treatments as presented in Table 2. Also, terminal or middle parts of branch were higher in spurs than the basal part in the two seasons of study. However, basal part of control trees and terminal part of shortening 1/2 branches level treatments were did not formed any spurs in the two seasons. In addition, shortening 1/3 branch level and tipping treatments with NAA + bending were most effective for spurs formations at the terminal part in

Table 1: Effect of heading cut levels, bending and NAA on total number of spurs/shoot of Sun Gold plum cultivar (Seasons 2008/2009 and 2009/2010)

| Winter heading cut level treatments | Spring and summer applications | Total number of spurs / shoot Seasons 2008/2009 | 2009/2010 | Average |
|---|---|---|---|---|
| Control | NAA | 3.30 | 3.54 | 3.42 |
| | Bending | 4.93 | 6.59 | 5.76 |
| | NAA+Bending | 5.47 | 6.82 | 6.15 |
| | Without | 3.00 | 3.22 | 3.11 |
| | Average | 4.18 | 5.04 | 4.61 |
| Tipping (0.5-1 cm) | NAA | 6.90 | 8.22 | 7.56 |
| | Bending | 8.60 | 9.63 | 9.12 |
| | NAA+Bending | 10.16 | 10.45 | 10.31 |
| | Without | 6.43 | 6.66 | 6.55 |
| | Average | 8.02 | 8.74 | 8.38 |
| Shortening (1/3 length) | NAA | 5.57 | 7.92 | 6.75 |
| | Bending | 7.48 | 8.52 | 8.00 |
| | NAA+Bending | 8.70 | 10.09 | 9.40 |
| | Without | 5.15 | 7.77 | 6.46 |
| | Average | 6.73 | 8.58 | 7.65 |
| Shortening (1/2 length) | NAA | 4.86 | 5.12 | 4.99 |
| | Bending | 5.91 | 6.60 | 6.26 |
| | NAA+Bending | 8.04 | 8.59 | 8.32 |
| | Without | 3.42 | 3.92 | 3.67 |
| | Average | 5.56 | 6.06 | 5.81 |
| General average | 6.12 | 7.11 | 6.62 | |
| Average of spring and summer applications | NAA | 5.16 | 6.20 | 5.68 |
| | Bending | 6.73 | 7.84 | 7.29 |
| | NAA+Bending | 8.09 | 8.99 | 8.54 |
| | Without | 4.50 | 5.39 | 4.95 |
| LSD at 5% | | | | |
| Winter heading cut levels (A) | | | 0.32 | |
| Spring and summer applications (B) | | | 0.32 | |
| Seasons (C) | | | 0.23 | |
| AXB | | | 0.64 | |
| AXC | | | 0.45 | |
| BXC | | | 0.45 | |
| AXBXC | | | 0.90 | |

Table 2: Effect of heading cut levels, bending and NAA on spurs distribution per shoot parts of Sun Gold plum cultivar (Seasons 2008/2009and2009/2010)

| Winter heading cut level treatments | Spring and summer applications | Spurs distribution/shoot parts 2008/2009 Basal | Middle | terminal | Av. | 2009/2010 Basal | Middle | Terminal | Av. |
|---|---|---|---|---|---|---|---|---|---|
| Control | NAA | 0.00 | 1.30 | 2.00 | 1.10 | 0.00 | 1.65 | 1.89 | 1.18 |
| | Bending | 0.00 | 1.92 | 3.01 | 1.64 | 0.00 | 2.06 | 4.53 | 2.20 |
| | NAA+Bending | 0.00 | 1.52 | 3.95 | 1.82 | 0.00 | 2.49 | 4.32 | 2.27 |
| | Without | 0.00 | 0.45 | 2.55 | 1.00 | 0.00 | 0.75 | 2.47 | 1.07 |
| | Average | 0.00 | 1.30 | 2.88 | 1.39 | 0.00 | 1.74 | 3.30 | 1.68 |
| Tipping (0.5-1 cm) | NAA | 1.46 | 2.22 | 3.22 | 2.30 | 1.82 | 2.44 | 3.96 | 2.74 |
| | Bending | 1.33 | 3.24 | 4.03 | 2.87 | 1.65 | 3.71 | 4.27 | 3.21 |
| | NAA+Bending | 2.31 | 3.62 | 4.23 | 3.39 | 2.49 | 4.15 | 3.81 | 3.48 |
| | Without | 1.74 | 2.30 | 2.39 | 2.14 | 1.56 | 2.74 | 2.36 | 2.22 |
| | Average | 1.71 | 2.85 | 3.47 | 2.68 | 1.88 | 3.26 | 3.60 | 2.91 |
| Shortening (1/3 length) | NAA | 1.46 | 1.69 | 2.42 | 1.86 | 1.75 | 1.73 | 4.44 | 2.64 |
| | Bending | 1.60 | 2.59 | 3.29 | 2.49 | 1.64 | 2.83 | 4.05 | 2.84 |
| | NAA+Bending | 1.46 | 2.49 | 4.75 | 2.90 | 1.66 | 3.29 | 5.14 | 3.36 |
| | Without | 1.24 | 1.87 | 2.04 | 1.72 | 1.35 | 1.85 | 4.57 | 2.59 |
| | Average | 1.44 | 2.16 | 3.13 | 2.24 | 1.60 | 2.43 | 4.55 | 2.86 |

Table 2: Continued

| Winter heading cut level treatments | Spring and summer applications | Spurs distribution/shoot parts 2008/2009 Basal | Middle | terminal | Av. | 2009/2010 Basal | Middle | Terminal | Av. |
|---|---|---|---|---|---|---|---|---|---|
| Shortening (1/2 length) | NAA | 1.82 | 3.04 | 0.00 | 1.62 | 1.95 | 3.17 | 0.00 | 1.71 |
| | Bending | 2.16 | 3.75 | 0.00 | 1.97 | 2.64 | 3.96 | 0.00 | 2.20 |
| | NAA+Bending | 3.42 | 4.62 | 0.00 | 2.68 | 3.70 | 4.89 | 0.00 | 2.86 |
| | Without | 1.50 | 1.92 | 0.00 | 1.14 | 1.82 | 2.10 | 0.00 | 1.31 |
| | Average | 2.23 | 3.33 | 0.00 | 1.85 | 2.53 | 3.53 | 0.00 | 2.02 |
| General average | 1.35 | 2.41 | 2.37 | 2.04 | 1.50 | 2.74 | 2.86 | 2.37 | |
| Average of spring and summer applications | NAA | 1.19 | 2.06 | 1.91 | 1.72 | 1.38 | 2.25 | 2.57 | 2.07 |
| | Bending | 1.27 | 2.88 | 2.58 | 2.24 | 1.48 | 3.14 | 3.21 | 2.61 |
| | NAA+Bending | 1.80 | 3.06 | 3.23 | 2.69 | 1.96 | 3.71 | 3.32 | 2.99 |
| | Without | 1.12 | 1.64 | 1.75 | 1.50 | 1.18 | 1.86 | 2.35 | 1.80 |
| LSD at 5% | | | | | | | | | |
| Winter heading cut level (A) | | | 0.08 | | | | 0.08 | | |
| Spring and summer applications (B) | | | 0.08 | | | | 0.08 | | |
| Spurs distribution(C) | | | 0.06 | | | | 0.07 | | |
| AXB | | | 0.16 | | | | 0.15 | | |
| AXC | | | 0.14 | | | | 0.13 | | |
| BXC | | | 0.14 | | | | 0.13 | | |
| AXBXC | | | 0.28 | | | | 0.26 | | |

Table 3: Effect of heading cut levels, bending and NAA on C/N ratio of Sun Gold plum cultivar (Season 2008/2009)

| Winter heading cut level treatments | Spring and summer applications | C/N ratio 2008/2009 15/9 | 15/10 | 15/11 | 15/12 | 15/1 | Av. |
|---|---|---|---|---|---|---|---|
| Control | NAA | 11.32 | 11.09 | 12.59 | 13.76 | 14.99 | 12.75 |
| | Bending | 12.38 | 12.41 | 13.56 | 13.62 | 15.00 | 13.39 |
| | NAA+Bending | 12.71 | 13.43 | 14.75 | 14.12 | 15.17 | 14.03 |
| | Without | 10.08 | 11.63 | 11.51 | 12.20 | 12.87 | 11.66 |
| | Average | 11.62 | 12.14 | 13.10 | 13.43 | 14.51 | 12.96 |
| Tipping (0.5-1cm) | NAA | 17.34 | 16.65 | 16.55 | 16.66 | 17.22 | 16.88 |
| | Bending | 18.62 | 19.03 | 19.66 | 18.09 | 18.62 | 18.80 |
| | NAA+Bending | 21.52 | 21.64 | 21.13 | 21.23 | 20.74 | 21.25 |
| | Without | 15.90 | 16.16 | 15.66 | 15.50 | 16.29 | 15.90 |
| | Average | 18.34 | 18.37 | 18.25 | 17.87 | 18.22 | 18.21 |
| Shortening (1/3 length) | NAA | 18.24 | 17.54 | 18.20 | 18.60 | 18.88 | 18.29 |
| | Bending | 18.87 | 20.34 | 19.54 | 19.79 | 19.57 | 19.62 |
| | NAA+Bending | 25.96 | 25.01 | 24.35 | 25.5 | 24.05 | 24.97 |
| | Without | 15.87 | 15.38 | 16.24 | 16.73 | 16.56 | 16.16 |
| | Average | 19.74 | 19.57 | 19.58 | 20.16 | 19.76 | 19.76 |
| Shortening (1/2 length) | NAA | 13.82 | 14.27 | 15.32 | 14.88 | 15.17 | 14.69 |
| | Bending | 14.30 | 14.32 | 15.09 | 16.07 | 16.24 | 15.20 |
| | NAA+Bending | 15.30 | 14.05 | 15.48 | 16.40 | 15.98 | 15.44 |
| | Without | 13.65 | 13.65 | 14.37 | 15.16 | 15.00 | 14.37 |
| | Average | 14.27 | 14.07 | 15.06 | 15.63 | 15.60 | 14.93 |
| General average | 15.99 | 16.04 | 16.50 | 16.77 | 17.02 | 16.46 | |
| Average of spring and summer applications | NAA | 15.18 | 14.89 | 15.66 | 15.98 | 16.57 | 15.65 |
| | Bending | 16.04 | 16.52 | 16.96 | 16.89 | 17.36 | 16.75 |
| | NAA+Bending | 18.87 | 18.53 | 18.93 | 19.31 | 18.99 | 18.92 |
| | Without | 13.88 | 14.20 | 14.44 | 14.90 | 15.18 | 14.52 |
| LSD at 5% | | | | | | | |
| Winter heading cut level (A) | | | 0.17 | | | | |
| Spring and summer applications (B) | | | 0.17 | | | | |
| Date of sample(C) | | | 0.19 | | | | |
| AXB | | | 0.33 | | | | |
| AXC | | | 0.37 | | | | |
| BXC | | | 0.37 | | | | |
| AXBXC | | | 0.75 | | | | |

Table 4: Effect of heading cut levels, bending and NAA on C/N ratio of Sun Gold plum cultivar (Season 2009/2010)

| | | C/N ratio | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2009/2010 | | | | | |
| Winter heading cut level treatments | Spring and summer applications | 15/9 | 15/10 | 15/11 | 15/12 | 15/1 | Av. |
| Control | NAA | 12.75 | 13.96 | 12.80 | 14.07 | 14.31 | 13.58 |
| | Bending | 13.55 | 14.77 | 13.36 | 14.41 | 14.14 | 14.05 |
| | NAA+Bending | 14.65 | 14.80 | 13.90 | 13.89 | 14.81 | 14.41 |
| | Without | 11.88 | 13.10 | 12.81 | 13.15 | 13.50 | 12.89 |
| | Average | 13.21 | 14.16 | 13.22 | 13.88 | 14.19 | 13.73 |
| Tipping (0.5-1cm) | NAA | 17.68 | 18.62 | 18.54 | 19.10 | 19.33 | 18.65 |
| | Bending | 20.03 | 20.73 | 21.92 | 22.37 | 22.06 | 21.42 |
| | NAA+Bending | 24.17 | 24.92 | 25.65 | 23.56 | 24.29 | 24.52 |
| | Without | 16.61 | 17.19 | 16.67 | 17.54 | 18.41 | 17.28 |
| | Average | 19.62 | 20.36 | 20.69 | 20.64 | 21.02 | 20.47 |
| Shortening (1/3 length) | NAA | 21.05 | 21.10 | 21.19 | 21.75 | 20.85 | 21.19 |
| | Bending | 21.58 | 22.94 | 23.28 | 22.09 | 22.99 | 22.58 |
| | NAA+Bending | 26.17 | 27.77 | 27.08 | 25.80 | 26.70 | 26.70 |
| | Without | 18.39 | 18.74 | 19.34 | 19.69 | 20.71 | 19.37 |
| | Average | 21.80 | 22.64 | 22.72 | 22.33 | 22.81 | 22.46 |
| Shortening (1/2 length) | NAA | 14.45 | 14.48 | 14.76 | 14.75 | 15.69 | 14.83 |
| | Bending | 14.18 | 14.29 | 14.64 | 15.07 | 15.79 | 14.79 |
| | NAA+Bending | 17.34 | 17.73 | 16.19 | 16.36 | 17.30 | 16.98 |
| | Without | 13.90 | 13.94 | 14.90 | 15.33 | 14.80 | 14.57 |
| | Average | 14.97 | 15.11 | 15.12 | 15.38 | 15.89 | 15.29 |
| General average | 17.40 | 18.07 | 17.94 | 18.06 | 18.48 | 17.99 | |
| Average of spring and summer aplications | NAA | 16.48 | 17.04 | 16.82 | 17.42 | 17.55 | 17.06 |
| | Bending | 17.33 | 18.18 | 18.30 | 18.49 | 18.75 | 18.21 |
| | NAA+Bending | 20.58 | 21.31 | 20.70 | 19.90 | 20.77 | 20.65 |
| | Without | 15.19 | 15.74 | 15.93 | 16.43 | 16.85 | 16.03 |
| LSD at 5% | | | | | | | |
| Winter heading cut level treatments (A) | | | 0.17 | | | | |
| Spring and summer applications (B) | | | 0.17 | | | | |
| Date of sample(C) | | | 0.19 | | | | |
| AXB | | | 0.34 | | | | |
| AXC | | | 0.38 | | | | |
| BXC | | | 0.38 | | | | |
| AXBXC | | | 0.76 | | | | |

the two seasons. However, shortening 1/2 branch level with NAA + bending treatment was more effective for spurs formation at middle part in both seasons under study. The superiority of tipping with spraying NAA + bending treatment may be due to effectiveness for former mean rather faster one for controlling apical dominance phenomenon i.e., the inhibition of lateral bud growth by auxin emanating from the apical bud [33]. Moreover, increasing the shoot angle by bending known to increase the lateral spurs number at terminal part of branch [17-19].

**C/N Ratio:** Data presented in Tables 3 and 4 revealed that shortening 1/3 branches level treatment increased C/N ratio in spurs and buds plus nodal tissues followed by toping, shortening 1/2 branches level then control trees in both seasons. Also, the combination between NAA + bending application gave the highest value in this concern. Generally, C/N ratio was significantly increased from 15$^{th}$ September till 15$^{th}$ January in both seasons. Also, shortening 1/3 branches level with NAA + bending treatment gave the highest C/N ratio compared to other treatments in all samples date under study.

In this respect, total carbohydrate and C/N ratio were significantly increased in spurs and buds of pruned trees affecting by different heading cut levels with NAA and / or bending. This may be due to increasing leaf chlorophyll content and photosynthesis rate activity [17-19, 34, 35]. Also, these results may be due to horizontal branches system (bending) which gave higher C/N ratio, in wood tissues, than vertical system [14]. Moreover, bending shoots to horizontal position is known to slow down shoot growth [15, 16].

Table 5: Effect of heading cut levels, bending and NAA on yield (Kg/tree) of Sun Gold plum cultivar (Seasons 2008/2009 and 2009/2010)

| | | Yield (Kg/tree) | | |
|---|---|---|---|---|
| | | Seasons | | |
| Winter heading cut level treatments | Spring and summer applications | 2008/2009 | 2009/2010 | Average |
| Control | NAA | 18.82 | 19.46 | 19.14 |
| | Bending | 20.73 | 22.22 | 21.47 |
| | NAA+Bending | 22.13 | 23.51 | 22.82 |
| | Without | 13.15 | 15.25 | 14.20 |
| | Average | 18.71 | 20.11 | 19.41 |
| Tipping (0.5-1cm) | NAA | 28.63 | 30.62 | 29.63 |
| | Bending | 33.11 | 32.07 | 32.59 |
| | NAA+Bending | 36.51 | 37.07 | 36.79 |
| | Without | 28.27 | 25.51 | 26.89 |
| | Average | 31.63 | 31.32 | 31.47 |
| Shortening (1/3 length) | NAA | 31.93 | 33.09 | 32.51 |
| | Bending | 33.78 | 35.41 | 34.60 |
| | NAA+Bending | 35.20 | 37.62 | 36.41 |
| | Without | 29.60 | 32.29 | 30.94 |
| | Average | 32.63 | 34.60 | 33.62 |
| Shortening (1/2 length) | NAA | 21.47 | 21.28 | 21.38 |
| | Bending | 21.68 | 22.86 | 22.27 |
| | NAA+Bending | 21.91 | 24.21 | 23.06 |
| | Without | 19.49 | 20.87 | 20.18 |
| | Average | 21.14 | 22.31 | 21.72 |
| General average | 26.03 | 27.08 | 26.56 | |
| Average of spring and summer applications | NAA | 25.21 | 26.11 | 25.66 |
| | Bending | 27.33 | 28.14 | 27.73 |
| | NAA+Bending | 28.94 | 30.60 | 29.77 |
| | Without | 22.63 | 23.48 | 23.05 |
| LSD at 5% | | | | |
| Winter heading cut level (A) | | | 0.87 | |
| Spring and summer applications(B) | | | 0.87 | |
| Seasons(C) | | | 0.61 | |
| AXB | | | 1.74 | |
| AXC | | | 1.23 | |
| BXC | | | 1.23 | |
| AXBXC | | | 2.45 | |

**Yield (Kg/tree):** Table 5 show that yield per trees was significantly affected by all treatments under study compared to the untreated ones (control) in both seasons. Concerning the winter heading cut levels treatments effect, shortening 1/3 branches level treatment gave the highest average of yield (33.62 Kg/tree) followed tipping (31.47 Kg/tree), shortening 1/2 branches level (21.72 Kg/tree) then control trees (19.41 Kg/tree). However, spring spraying of NAA at 150 ppm plus summer bending application gave the highest yield compared to single application of NAA or bending alone in both seasons. Also, the yield/tree was increased in the second season than in the first one. Concerning the interaction between headings cut levels and spring and summer applications, tipping or shortening 1/3 branches level with NAA + bending gave the best results during two seasons under study.

These results are parallel with the data of Mika [7], who found that dormant pruning resulted in greater yield per tree than any pruning date. Heading cut through branches and bending increased the yield of plum trees [22, 23, 36]. Also, the yield of plum trees was increased affecting by NAA application at the time of petals fall and distinctly visible abscission zone between the floral tube and the pedicle [24].

**Fruit Physical Properties:** As shown in Tables 6-8, weight, size, length, diameter, shape and flesh thickness of Sun Gold plum fruits were affected significantly by different winter heading cut levels and spring and summer application treatments. The highest values of all parameters except fruit shape were recorded by shortening 1/3 branches level followed by shortening 1/2 branches level, tipping then control trees in both seasons.

Table 6: Effect of heading cut levels, bending and NAA on fruit weight and size of Sun Gold plum cultivar (Seasons 2008/2009 and 2009/2010)

| Winter heading cut level treatments | Spring and summer applications | Fruit weight (gm) | | | Fruit size ($cm^3$) | | |
|---|---|---|---|---|---|---|---|
| | | 2008/2009 | 2009/2010 | Average | 2008/2009 | 2009/2010 | Average. |
| Control | NAA | 29.65 | 30.18 | 29.92 | 28.44 | 29.32 | 28.88 |
| | Bending | 30.49 | 31.26 | 30.88 | 29.32 | 30.60 | 29.96 |
| | NAA+Bending | 31.80 | 32.44 | 32.12 | 30.65 | 31.38 | 31.01 |
| | Without | 26.31 | 27.09 | 26.70 | 25.14 | 26.62 | 25.88 |
| | Average | 29.56 | 30.24 | 29.90 | 28.39 | 29.48 | 28.93 |
| Tipping (0.5-1 cm) | NAA | 35.62 | 35.82 | 35.72 | 34.40 | 34.70 | 34.55 |
| | Bending | 37.42 | 35.97 | 36.69 | 36.13 | 36.67 | 36.40 |
| | NAA+Bending | 39.69 | 40.52 | 40.10 | 38.26 | 39.11 | 38.69 |
| | Without | 34.48 | 32.21 | 33.35 | 33.53 | 34.46 | 33.99 |
| | Average | 36.80 | 36.13 | 36.47 | 35.58 | 36.24 | 35.91 |
| Shortening (1/3 length) | NAA | 45.52 | 45.33 | 45.42 | 44.18 | 44.30 | 44.24 |
| | Bending | 46.15 | 46.30 | 46.22 | 45.34 | 45.10 | 45.22 |
| | NAA+Bending | 46.27 | 47.94 | 47.10 | 46.90 | 46.72 | 46.81 |
| | Without | 44.18 | 43.53 | 43.85 | 44.50 | 42.29 | 43.40 |
| | Average | 45.53 | 45.77 | 45.65 | 45.23 | 44.60 | 44.92 |
| Shortening (1/2 length) | NAA | 42.10 | 40.16 | 41.13 | 41.36 | 42.76 | 42.06 |
| | Bending | 44.98 | 45.72 | 45.35 | 43.51 | 44.80 | 44.15 |
| | NAA+Bending | 45.9 | 46.39 | 46.15 | 44.66 | 45.68 | 45.17 |
| | Without | 41.74 | 42.66 | 42.20 | 40.67 | 41.91 | 41.29 |
| | Average | 43.68 | 43.70 | 43.71 | 42.55 | 43.79 | 43.17 |
| General average | 38.89 | 38.97 | 38.93 | 37.94 | 38.53 | 38.24 | |
| Average of spring and summer applications | NAA | 38.22 | 37.87 | 38.05 | 37.10 | 37.77 | 37.43 |
| | Bending | 39.76 | 39.81 | 39.79 | 38.58 | 39.29 | 38.93 |
| | NAA+Bending | 40.92 | 41.82 | 41.37 | 40.12 | 40.72 | 40.42 |
| | Without | 36.68 | 36.37 | 36.53 | 35.96 | 36.32 | 36.14 |
| LSD at 5% | | | | | | | |
| Winter heading cut level (A) | | | 0.61 | | | 0.58 | |
| Spring and summer applications (B) | | | 0.61 | | | 0.58 | |
| Seasons(C) | | | 0.43 | | | 0.41 | |
| AXB | | | 1.22 | | | 1.16 | |
| AXC | | | 0.86 | | | 0.82 | |
| BXC | | | 0.86 | | | 0.82 | |
| AXBXC | | | 1.72 | | | 1.64 | |

Table 7: Effect of heading cut levels, bending and NAA on fruit length and diameter of Sun Gold plum cultivar (Seasons 2008/2009 and 2009/2010)

| Winter heading cut level treatments | Spring and summer applications | Fruit length (cm) | | | Fruit diameter (cm) | | |
|---|---|---|---|---|---|---|---|
| | | 2008/2009 | 2009/2010 | Average | 2008/2009 | 2009/2010 | Average. |
| Control | NAA | 2.45 | 3.15 | 2.80 | 2.37 | 2.98 | 2.67 |
| | Bending | 3.40 | 3.00 | 3.20 | 3.22 | 2.90 | 3.06 |
| | NAA+Bending | 3.21 | 3.35 | 3.28 | 3.00 | 3.20 | 3.10 |
| | Without | 2.62 | 3.00 | 2.81 | 2.50 | 2.82 | 2.66 |
| | Average | 2.92 | 3.13 | 3.02 | 2.77 | 2.97 | 2.87 |
| Tipping (0.5-1cm) | NAA | 3.65 | 3.69 | 3.67 | 3.53 | 3.66 | 3.59 |
| | Bending | 3.65 | 3.72 | 3.68 | 3.51 | 3.58 | 3.54 |
| | NAA+Bending | 3.73 | 3.57 | 3.65 | 3.61 | 3.79 | 3.70 |
| | Without | 3.58 | 3.76 | 3.67 | 3.48 | 3.66 | 3.57 |
| | Average | 3.65 | 3.68 | 3.67 | 3.53 | 3.67 | 3.60 |
| Shortening (1/3 length) | NAA | 3.95 | 4.41 | 4.18 | 3.75 | 4.00 | 3.87 |
| | Bending | 4.02 | 4.48 | 4.25 | 3.97 | 4.07 | 4.02 |
| | NAA+Bending | 4.15 | 4.60 | 4.37 | 4.07 | 4.12 | 4.09 |
| | Without | 3.89 | 4.35 | 4.12 | 3.69 | 4.04 | 3.86 |
| | Average | 4.00 | 4.46 | 4.23 | 3.87 | 4.05 | 3.96 |
| Shortening (1/2 length) | NAA | 4.01 | 4.15 | 4.08 | 3.59 | 3.92 | 3.75 |
| | Bending | 4.09 | 4.23 | 4.16 | 3.64 | 3.97 | 3.80 |
| | NAA+Bending | 4.20 | 4.25 | 4.22 | 3.97 | 4.00 | 3.91 |
| | Without | 4.12 | 4.25 | 4.18 | 3.54 | 3.54 | 3.70 |
| | Average | 4.10 | 4.22 | 4.16 | 3.64 | 3.94 | 3.79 |
| General average | 3.67 | 3.87 | 3.77 | 3.45 | 3.66 | 3.55 | |

Table 7: Continued

| Winter heading cut level treatments | Spring and summer applications | Fruit length (cm) | | | Fruit diameter (cm) | | |
|---|---|---|---|---|---|---|---|
| | | 2008/2009 | 2009/2010 | Average | 2008/2009 | 2009/2010 | Average |
| Average of spring and summer applications | NAA | 3.51 | 3.85 | 3.68 | 3.31 | 3.64 | 3.47 |
| | Bending | 3.79 | 3.85 | 3.82 | 3.58 | 3.63 | 3.60 |
| | NAA+Bending | 3.82 | 3.94 | 3.88 | 3.62 | 3.77 | 3.70 |
| | Without | 3.55 | 3.84 | 3.69 | 3.30 | 3.59 | 3.45 |
| LSD at 5% | | | | | | | |
| Winter heading cut level (A) | | | 0.18 | | | 0.15 | |
| Spring and summer applications(B) | | | 0.18 | | | 0.15 | |
| Seasons(C) | | | 0.13 | | | 0.11 | |
| AXB | | | 0.37 | | | 0.31 | |
| AXC | | | 0.26 | | | 0.22 | |
| BXC | | | 0.26 | | | 0.22 | |
| AXBXC | | | 0.52 | | | 0.43 | |

Table 8: Effect of heading cut levels, bending and NAA on fruit shape and flesh thickness of Sun Gold plum cultivar (Seasons 2008/2009 and 2009/2010)

| Winter heading cut level treatments | Spring and summer applications | Fruit shape (L/D ratio) | | | Flesh thickness (cm) | | |
|---|---|---|---|---|---|---|---|
| | | 2008/2009 | 2009/2010 | Average | 2008/2009 | 2009/2010 | Average. |
| Control | NAA | 1.033 | 1.057 | 1.045 | 1.03 | 1.03 | 1.15 |
| | Bending | 1.055 | 1.034 | 1.044 | 1.28 | 1.34 | 1.31 |
| | NAA+Bending | 1.070 | 1.046 | 1.058 | 1.30 | 1.40 | 1.35 |
| | Without | 1.048 | 1.063 | 1.055 | 1.05 | 1.21 | 1.13 |
| | Average | 1.051 | 1.050 | 1.050 | 1.16 | 1.30 | 1.23 |
| Tipping (0.5-1cm) | NAA | 1.033 | 1.008 | 1.021 | 1.42 | 1.43 | 1.42 |
| | Bending | 1.039 | 1.039 | 1.039 | 1.56 | 1.60 | 1.58 |
| | NAA+Bending | 1.033 | 1.031 | 1.032 | 1.66 | 1.71 | 1.68 |
| | Without | 1.028 | 1.027 | 1.027 | 1.37 | 1.40 | 1.38 |
| | Average | 1.033 | 1.026 | 1.029 | 1.50 | 1.53 | 1.51 |
| Shortening (1/3 length) | NAA | 1.053 | 1.088 | 1.070 | 1.76 | 1.80 | 1.78 |
| | Bending | 1.012 | 1.010 | 1.011 | 1.89 | 1.95 | 1.92 |
| | NAA+Bending | 1.019 | 1.116 | 1.067 | 1.96 | 1.96 | 1.97 |
| | Without | 1.083 | 1.076 | 1.079 | 1.70 | 1.75 | 1.72 |
| | Average | 1.041 | 1.072 | 1.056 | 1.82 | 1.87 | 1.85 |
| Shortening (1/2 length) | NAA | 1.116 | 1.058 | 1.087 | 1.76 | 1.82 | 1.79 |
| | Bending | 1.123 | 1.065 | 1.090 | 1.83 | 1.86 | 1.84 |
| | NAA+Bending | 1.099 | 1.024 | 1.061 | 1.85 | 1.90 | 1.87 |
| | Without | 1.129 | 1.098 | 1.113 | 1.64 | 1.70 | 1.67 |
| | Average | 1.117 | 1.061 | 1.089 | 1.77 | 1.82 | 1.79 |
| General average | 1.061 | 1.052 | 1.056 | 1.56 | 1.63 | 1.60 | |
| Average of spring and summer applications | NAA | 1.059 | 1.053 | 1.055 | 1.49 | 1.58 | 1.53 |
| | Bending | 1.057 | 1.037 | 1.039 | 1.64 | 1.68 | 1.66 |
| | NAA+Bending | 1.055 | 1.054 | 1.054 | 1.69 | 1.74 | 1.72 |
| | Without | 1.073 | 1.066 | 1.069 | 1.44 | 1.51 | 1.47 |
| LSD at 5% | | | | | | | |
| Winter heading cut level (A) | | | 0.02 | | | 0.03 | |
| Spring and summer applications (B) | | | 0.02 | | | 0.03 | |
| Seasons(C) | | | 0.01 | | | 0.02 | |
| AXB | | | 0.04 | | | 0.06 | |
| AXC | | | 0.03 | | | 0.04 | |
| BXC | | | 0.03 | | | 0.04 | |
| AXBXC | | | 0.05 | | | 0.09 | |

Table 9: Effect of heading cut levels, bending and NAA on fruit TSS and acidity of Sun Gold plum cultivar (Seasons 2008/2009 and 2009/2010)

| Winter heading cut level treatments | Spring and summer applications | TSS (%) | | | Acidity (%) | | |
|---|---|---|---|---|---|---|---|
| | | 2008/2009 | 2009/2010 | Average | 2008/2009 | 2009/2010 | Average. |
| Control | NAA | 11.60 | 12.50 | 12.05 | 0.875 | 0.892 | 0.883 |
| | Bending | 11.65 | 12.55 | 12.10 | 0.882 | 0.863 | 0.872 |
| | NAA+Bending | 11.80 | 12.65 | 12.23 | 0.870 | 0.840 | 0.855 |
| | Without | 11.40 | 12.39 | 11.90 | 0.894 | 0.853 | 0.873 |
| | Average | 11.61 | 12.52 | 12.07 | 0.880 | 0.862 | 0.871 |
| Tipping (0.5-1 cm) | NAA | 13.00 | 13.55 | 13.27 | 0.840 | 0.830 | 0.835 |
| | Bending | 13.20 | 14.10 | 13.65 | 0.850 | 0.880 | 0.865 |
| | NAA+Bending | 13.55 | 14.50 | 14.02 | 0.830 | 0.810 | 0.820 |
| | Without | 12.85 | 13.50 | 13.18 | 0.851 | 0.860 | 0.855 |
| | Average | 13.15 | 13.91 | 13.53 | 0.842 | 0.845 | 0.843 |
| Shortening (1/3 length) | NAA | 14.22 | 15.30 | 14.76 | 0.860 | 0.810 | 0.835 |
| | Bending | 14.60 | 15.50 | 15.05 | 0.865 | 0.820 | 0.842 |
| | NAA+Bending | 14.85 | 15.60 | 15.23 | 0.860 | 0.820 | 0.840 |
| | Without | 14.11 | 15.10 | 14.60 | 0.871 | 0.800 | 0.835 |
| | Average | 14.44 | 15.38 | 14.91 | 0.864 | 0.812 | 0.838 |
| Shortening (1/2 length) | NAA | 14.55 | 14.55 | 14.55 | 0.850 | 0.911 | 0.880 |
| | Bending | 14.70 | 14.70 | 14.70 | 0.921 | 0.850 | 0.885 |
| | NAA+Bending | 14.57 | 14.90 | 14.73 | 0.808 | 0.850 | 0.829 |
| | Without | 14.35 | 14.35 | 14.35 | 0.897 | 0.935 | 0.916 |
| | Average | 14.54 | 14.63 | 14.58 | 0.869 | 0.886 | 0.877 |
| General average | 13.44 | 14.11 | 13.78 | 0.864 | 0.851 | 0.858 | |
| Average of spring and summer applications | NAA | 13.34 | 13.98 | 13.66 | 0.856 | 0.860 | 0.858 |
| | Bending | 13.54 | 14.21 | 13.88 | 0.879 | 0.853 | 0.866 |
| | NAA+Bending | 13.69 | 14.41 | 14.05 | 0.842 | 0.830 | 0.836 |
| | Without | 13.18 | 13.84 | 13.51 | 0.878 | 0.862 | 0.870 |
| LSD at 5% | | | | | | | |
| Winter heading cut level (A) | | | 0.22 | | | 0.03 | |
| Spring and summer applications(B) | | | 0.22 | | | 0.03 | |
| Seasons(C) | | | 0.15 | | | 0.02 | |
| AXB | | | 0.43 | | | 0.05 | |
| AXC | | | 0.31 | | | 0.04 | |
| BXC | | | 0.31 | | | 0.04 | |
| AXBXC | | | 0.61 | | | 0.07 | |

Also, the highest values of fruit physical parameters, except fruit shape, were obtained by NAA + bending followed by bending, NAA then control treatment. In addition, shortening 1/3 branches level + spraying NAA + bending treatment gave the best fruit physical properties compared other treatments in both seasons under study. In other words, fruits of higher shape index values were oblong shape, whereas those of lower shape index values appeared to be round shape.

**Fruit Chemical Properties:** Data in Table 9 clarify variations in chemical properties as a result of all conducted treatments. Juice TSS was significantly increased by all treatments in both seasons. Shortening 1/3 branches level with spraying NAA + bending treatment gave the highest TSS value (14.85 and 15.60%) compared to other treatments and control trees (11.40 and 12.39) in the two seasons. On the other hand, shortening 1/3 branches level with NAA + bending treatment gave the lowest fruit acidity level compared other treatment under study in both seasons.

These results (yield and fruit quality) may be achieved due to increasing in C/N ratio in wood tissues, photosynthesis rate activity and the balance between growth and fruiting in plum trees [2, 3, 10]. Similarly, it was stated that pruning had enhanced fruit physical and chemical parameter of plum, peach, apricot and apple trees [8, 9, 22, 23, 30, 37, 38].

## CONCLUSION

Winter tipping with spring spraying of NAA plus summer bending treatment gave the highest number of spurs formed per branch, especially, at terminal shoot part. Whereas, optimizing yield and fruit quality were obtained by winter shortening 1/3 branches level with spring spraying of NAA plus summer bending treatment.

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