Importance of crop load management in apple: An overview

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Abstract
To meet market demand and attain profitable fruit production, apple growers must produce fruits of good quality while retaining the highest possible yields. The conflicting nature of these two goals requires accurate management of tree crop load. Excessively low crop loads will lead to reduced productivity, despite a larger fruit size; while, with too many fruits, the yield per tree and per hectare will be reduced. In addition, excessive crop loads can result in alternate bearing in many apple cultivars. Successful fruit production is achieved by maintaining optimum crop load. Crop load management, therefore, is one of most important orchard management techniques used to improve crop yield and quality in apple.

Keywords: fruit production, crop loads, apple

1. Introduction
Crop load is the number of fruits /tree (Francesco et al., 1996; Wensche et al., 2005) [8]. It is often expressed in terms of number of fruit per trunk cross-sectional area (fruit/TCSA). Too heavy fruit load reduces fruit size and increase crop and vice versa (Mc Artney et al., 1996; Treder and Mika, 2001; Treder, 2008) [16, 30, 28]. Most apple cultivars have an over abundant flower density and percentage fruit set (Meland, 2009) [17]. Regulation of crop load is an effective method in apples to improve quality and to prevent biennial bearing (Link, 2000) [15]. Reducing the number of fruits /tree increase relative amount of photo assimilates for the remaining fruit. This also improves flower bud initiation and return bloom, and leads to more consistent annual yield (tromp, 2000) [31]. The consistent production of fruit of optimum color and size can only be accomplished when proper balance between vegetative growth and fruiting is maintained (Reginato, 2000) [24]. Crop has also an impact on the nutrient status of fruits. Irregular cropping results in insufficient nutrient uptake and disharmony of nutrients (Nagy et al., 2010) [18]. For this reason, regulation of crop load through thinning is imperative to obtain optimum yield of good quality fruits.

Results and Discussion
Fruit yield
Crop load is the most important factor that influence fruit yield. Low crop load has been found to decrease fruit yield (Palmer et al., 1997) [21]. Wertheim (1997) [35], Lepsis and Blanke (2004) [14] and Treder (2008) [28] reported a positive correlation between crop density and yield but negative correlation between crop density and fruit weight. Palmer et al. (1997) [21] reported that rate of fruit growth depends primarily on crop load. If the demand for photo assimilates exceeded the amount available early in the season, due to heavy crop load this leads to decreased fruit growth (Lakso et al., 1993) [13]. Giuliani et al. (1997) [9] reported that too intensive thinning reduces both yield and effectiveness of photosynthesis. Increasing fruit number per TCSA unit decreases the ratio of leaf area to TCSA and consequently, leaf area to fruit, resulting in a demand amount of available assimilates supporting fruit growth (Palmer et al., 1991) [20]. Voltz et al. (1993) [13] reported that light cropping and thinned trees have less flower bud density and greater fruit set than the heavy cropping trees. Treder (2010) [29] reported that there is positive correlation between crop density and yield. Palmer (1992) [19] reported that increase in crop load resulted in increase in total dry matter yield per unit leaf area and increase in yield efficiency beyond 10fruits/m² leaf area in Crispin M.27. Wunsche and Palmer (2000) [36] reported significant difference in yield per tree with varying crop loads.
**Fruit size**

Of all the factors that influence fruit size, crop load is the most important. Removing of a part of the crop is the most effective way to improve fruit size (Forshey, 1976) [8]. Overcropping resulted in a very poor fruit size (Jones et al., 1992) [11]. Early removal of fruit results in larger fruit size at harvest (Preston and Quinlan, 1968; Quinlan and Preston, 1968; Jones et al., 1992) [23, 25, 11]. Batjer (1965) [1] suggested that the increase in fruit size was roughly proportional to the crop retained on the tree. However, studies have shown the increase in fruit size was proportionately less than the reduction in fruit set (Batjer and Thomson, 1961; Rogers and Thompson, 1969) [2, 26] or in the number of fruits/tree (Southwick and Weeks, 1949; Way, 1965) [27, 34]. The close relationship between fruit numbers and yield regardless of tree size clearly indicates that this is the dominant factor contributing towards economic yield.

Fruit size is determined by cell number, cell size and intercellular space (Goffinet et al., 1995) [10]. However, cell number, which is determined early in apple development, accounts for most of the variation in fruit size (Pearson and Robertson, 1953) [22], and it can be influenced by previous year’s crop load and may reduce the number of cells in the flower receptacles if it is excessive (Bergh, 1992) [9]. When cell division is reduced by fruit competition during the early growth, optimum fruit size is not achieved. Previous results with many cultivars (Southwick and Weeks, 1949; Batjer and Westwood, 1960; Batjer and Thomson, 1961; Way, 1965; Rogers and Thompson, 1969) [27, 3, 2, 34, 20] demonstrated that increase in fruit size were proportionately less than the reduction in fruit numbers. The primary effect of fruit thinning on fruit size is more often a reduction in the number of smaller fruits than a dramatic increase in the size of the remaining fruits (Forshey and Elfving, 1977) [7].

The potential size of a given pome fruit is determined early in the season and growth proceeds at a relatively uniform rate thereafter. This uniform growth rate permits an accurate prediction of the harvest size of the fruit as early as mid-summer (Batjer et al., 1957) [4]. The growth rate, once established, is not easily altered, and fruit numbers, therefore, can affect fruit size only within definite limits and maximum effectiveness requires adjustment in fruit numbers relatively early in the season (Forshey and Elfving, 1977) [7]. Tukey (1970) [32] states, “thinning does not change a potentially small fruit into a large fruit, but rather insures that a potentially large fruit will size properly.” Emphasis should be on estimating fruit numbers rather than fruit size. Fruit thinning can quickly reach the point of diminishing returns. Rather than a high percentage of large fruits, the objectives of thinning should be the elimination of the smallest fruits, improved fruit quality and annual production (Forshey and Elfving, 1977) [7]. Koike and Ono (1998) [12] reported that crop load management by thinning is the most important step in order to harvest large, unique sized fruit. They reported that reducing initial fruit set of apples by eliminating a proportion of flowers during the bloom period is usually a highly desirable practice for improving fruit size in apple. Robinson et al. (2009) [21] showed that fruit size was reduced by increasing crop load in a curvilinear relationship. They found that fruit size was reduced rapidly as crop load increased from 0 to about 7 fruits/cm² TCSA and reported that to obtain optimum fruit size in Honeycrisp apple crop load of 5-6 fruits/cm²TCSA is required. Wunsche et al. (2005) [37] reported that at harvest fruit from light cropping trees were larger in size than in heavy cropping trees.

**Conclusion**

Crop load is the most important of all factors that influence fruit size, and removing of a part of the crop is the most effective way to improve fruit yield and fruit quality. Rather than a high percentage of large fruits, the objectives of thinning should be the elimination of the smallest fruits, improved fruit quality and annual production. Early removal of potential fruit (blossom thinning) should be used in apple to enhance flower initiation for next year’s crop and thus, return bloom. This type of thinning also reduces competition for carbohydrates among fruitlets.

**References**

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