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ORIGINAL PAPER

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ORCHARD PERFORMANCE OF APPLE WORSENS AS WEED COMPETITION INCREASES: A LONG-TERM FIELD STUDY UNDER MEDITERRANEAN CONDITIONS

Ersin Atay[1]✉, Seckin Gargin[1], Ahmet Esitken[2], Ayse Nilgun Atay[1], Mesut Altindal[1], Meltem Emre[1]

[1] TAGEM Fruit Research Institute, 32500, Egirdir, Isparta, Turkey

[2] Selcuk University, Faculty of Agriculture, Department of Horticulture, 42030, Konya, Turkey

ABSTRACT

Crop-weed competition (CWC) for water and nutrients can negatively affect orchard performance, especially in high-density apple orchards. With this study, we compared the effects of three CWC levels: Weak, Moderate, and Strong for the orchard performance of apple in the Mediterranean area. The study was conducted at a 'Golden Delicious'/M.9 orchard in a high-density formation (3.5 × 1 m spacing). Cumulative yield was greatest in Weak-CWC, and it decreased as CWC increased. Overall, Weak-CWC performed remarkable results for successful apple production under Mediterranean conditions.

Key words: apple, fruit set, *Malus* × *domestica*, organic matter, trunk cross-sectional area

INTRODUCTION

Fruit trees must be efficiently reached resources to sustain orchard productivity [Tworkoski and Glenn 2010]. Severe CWC can stunt the growth of young trees and reduce fruit quantity and quality in apple orchards [Merwin 2003]. CWC has a strong effect on growth, yield, soil properties and orchard profitability [Gut et al. 1996, Bissels et al. 2006]. Merwin and Ray [1997] suggested that a short weed control period (60–90 days) in early summer can show considerable results regarding tree growth and crop value in young apple orchards. Recently, Kim et al. [2015] showed that the income from fruit sales increased by 183% in the three- and four-fold weed interference compared to the severe CWC in a persimmon orchard.

We hypothesized that weed management itself determines orchard performance. The objectives of the study were to determine (1) cumulative yield, (2) trunk cross-sectional area (TCSA) increase, (3) fruit set, (4) soil organic matter, and (5) gross profit under three CWC levels in a 'Golden Delicious'/M.9 orchard in the Mediterranean area, one of the prime apple production area of the world.

MATERIALS AND METHODS

This study was conducted at Fruit Research Institute (MAREM) (latitude 37°48'52.07"N, longitude 30°52'39.63"E, altitude 919 m), located in the Mediterranean area of Turkey. The soil of the study orchard is clay-loam in texture. Table 1 offers detailed information on soil properties at the research area. Monthly weather data on precipitation and temperature at the research area are provided in Figure 1.

✉ atayersin@yahoo.com

Table 1. Soil properties of the research area (0–30 cm)

Soil property	Mean value
Saturaton (%)	71
EC (mS cm^{-1})	0.45
pH	7.94
Total lime (%)	7.16
Phosphorus (mg kg^{-1})	22
Potassium (mg kg^{-1})	371
Calcium (mg kg^{-1})	5143
Magnesium (mg kg^{-1})	678
Sodium (mg kg^{-1})	10.94
Iron (mg kg^{-1})	15.3
Copper (mg kg^{-1})	7.1
Manganese (mg kg^{-1})	9.4
Zinc (mg kg^{-1})	1.4

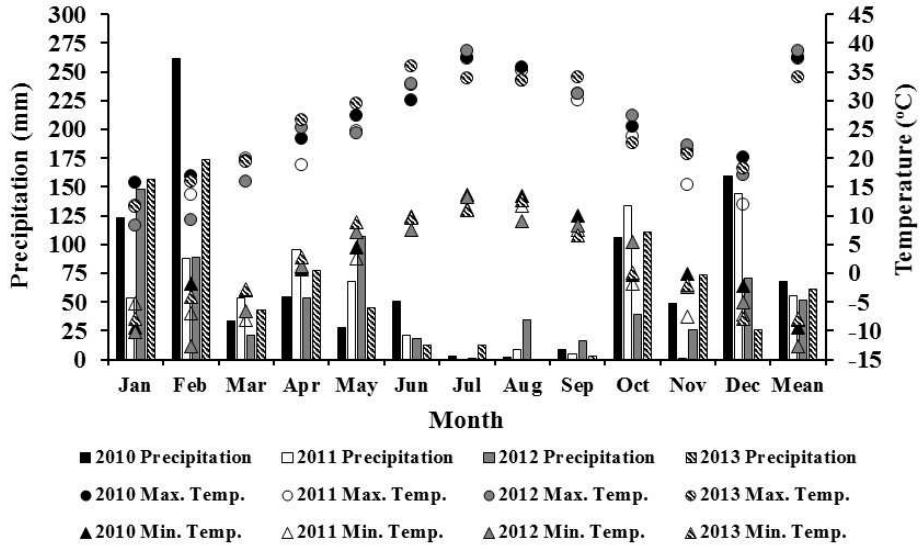

Fig. 1. Monthly total precipitation and mean temperature at the research area over four years (2010–2013). Mean: annual mean

'Golden Delicious'/M.9 apple was used for the study. The orchard was planted in spring 2005 with 3.5 × 1 m distances using one-year-old unbranched nursery trees. Trees had been trained since planting as the vertical axis and supported by a three-wire trellis up to 2.2 m high. 'Starking Delicious' apple was planted as the pollinator cultivator in the orchard. There were no pollination issues during the study and no blossom chemical thinning was applied. Hand-thinning at the end of the physiological drop was managed according

to local crop husbandry practices when crop load exceeded 4.5 fruit per cm^2 of branch cross-sectional area to leave one fruit per inflorescence.

Irrigation was applied until autumn rains (October), after which all trees were left unirrigated throughout the autumn and winter period. Two pipelines at a height above the ground of 45 cm were installed per tree row that was placed at 40 cm apart from each tree trunk towards to inter-row. The system had 4 L × h^{-1} pressure; in-line emitters spaced every 50 cm. Irrigation scheduling in the orchard was decided by MAREM's farm manager in according to grower irrigation in the region. In short, trees were irrigated with evapotranspiration-based full irrigation at 4-day intervals by drip irrigation. Trees were fertilized according to soil analysis with ammonium nitrate, mono ammonium phosphate, and potassium nitrate. Any organic compound and foliar fertilizers were not provided to the orchard throughout the study.

Tractor alleys between tree rows with naturally-occurred weeds were mowed with a tractor-mounted mower over time (usually three times per year) to 5–10 cm. 18 weed species were determined in the study orchard. Details for the weed species of the orchard can be found in Atay et al. [2013a]. This study focused on tree rows, and mowing was carried out with a grass cutter mower of 0.5 m on either side of the trees. Mowing to 1–5 cm, to suppress ground-cover vegetation in tree rows, was carried out at the following intervals: April + May –hereafter referred as Moderate-CWC and April through October – hereafter referred as Weak-CWC. Mowing in May was done one month later from first bloom in April (14.04.2010, 24.04.2011, 25.04.2012 and 18.04.2013), and the successive mowing interferences in Weak-CWC were applied at an interval of 1-month. In Strong-CWC, we did not treat weeds throughout the study. The same mowing applications were repeated over four subsequent years, from 2010 to 2013, using the same trees in the orchard. During the study, any damage from rodent, soil-borne root disease, and the cold injury did not occur in the orchard.

Yield at harvest was calculated regarding of t × ha^{-1}. For fruit set determination, three scaffold branches per block at breast height that were randomly chosen were tagged, and then it was expressed as follows: Fruit set = number of inflorescences with at least one fruit/total number of inflorescences [Lauri et al. 1996]. Counting of inflorescences and fruit were done at pink bud stage (BBCH Scale: 57) and after physiological fruit drop (BBCH Scale: 74) in 2014, respectively. Trunk diameter was measured in the dormant season over five subsequent years (2009–2013) at 15 cm above the budding point to determine TCSA. Soil samples at 0–30 cm depths were taken in winter (December) from the area between the tree trunk and irrigation pipeline to determine soil organic matter content.

One soil sample per block was taken (*i.e.* 3 × 1 = 3 soil samples in total per CWC). The classic Smith and Weldon [1940] method was used to determine the organic matter as percent (%). MAREM's economy team used the data of last two years (2012 and 2013) to perform economic analysis. In the estimates, costs (labour, material, and machinery) and fruit prices were considered. Fruit prices based on fruit diameter alone (>85 mm, 72 to 85 mm, 68 to 72 mm, 65 to 68 mm and <65 mm) were provided by a commercial storage company in the region (Gulbudak Ltd, Egirdir, Isparta; http://www.gulbudak.com.tr/en/).

The study was conducted in three tree rows with a completely randomised block design. Each CWC level had three replications of 4 experimental trees (*i.e.* 4 × 3 = 12 trees in total per CWC level) and those on either side acted as guard trees between the different CWC levels. Data were subjected to analysis of variance (ANOVA), and means were separated using Least Significant Difference (LSD) multiple range tests. A correlation analysis was performed to investigate relationships among annual TCSA increase and annual yield. The differences for significance was set at $P < 0.05$. Statistical analyses were performed using SAS-JMP software version 7.0 (http://www.jmp.com/software/).

RESULTS AND DISCUSSION

Annual yield varied biennially (fig. 1). Thus, 'Golden Delicious', the plant material of this study, has been found susceptible to biennial bearing in the

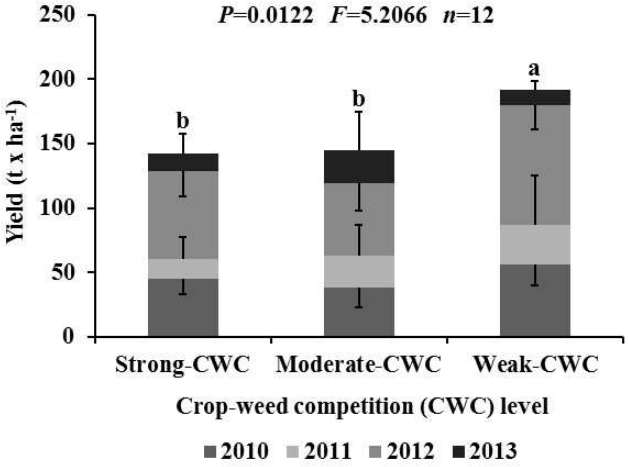

Fig. 1. Yield per ha from 2010 to 2013 of 'Golden Delicious'/M.9 apple. Different letters at the top of each bar designate crop-weed competition level effects on cumulative yield indicate significant differences at $P < 0.05$. The values of annual yield data shown are means ± standard deviation (SD)

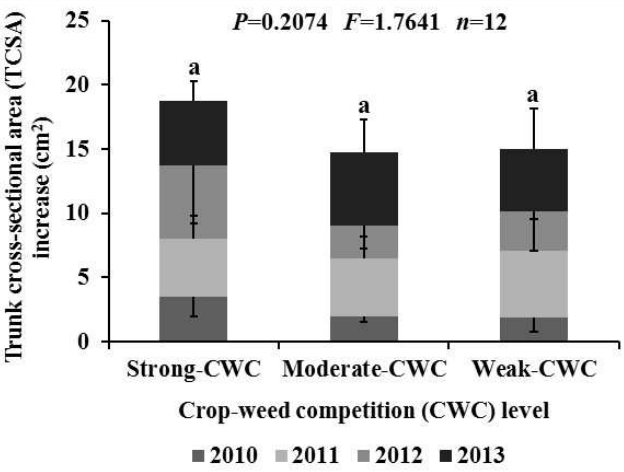

Fig. 3. Trunk cross-sectional area increase (TCSA) for each year from 2010 to 2013 in different crop-weed competition levels. The values of annual increase in TCSA shown are means ± SD

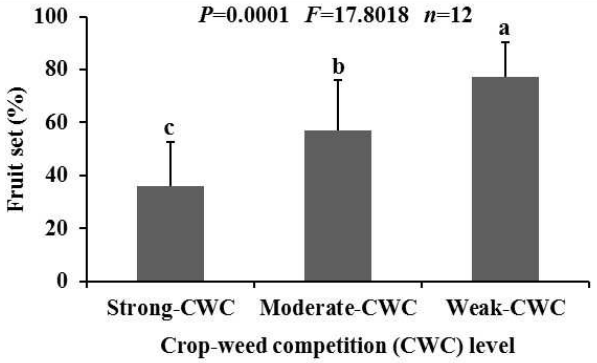

Fig. 2. Effect of crop-weed competition level on the fruit set of 'Golden Delicious'/M.9 apple in 2014. Different letters at the top of each bar indicate significant differences at $P < 0.05$. The values shown are means ± SD

local conditions of the study [Atay et al. 2013b]. The cumulative yield was affected by CWC levels. Weak-CWC showed greatest result for cumulative yield. Strong-CWC had relatively low cumulative yield with no significant differences from Moderate-CWC (fig. 1). Cumulative yield to decrease as CWC increase might be associated with tree nutritional status. Trees under stiff CWC might not be reserved nitrogen and other nutrients enough to perform a good orchard performance regarding yield. Thus, fruit set, under three different CWC levels, remained the same tendency as cumulative yield. Fruit set under Weak-CWC was greatest (77.40 ±13.09%), followed by the Moderate-CWC (57.00 ±19.13%) and Strong-CWC (36.11 ±16.66%), respectively (fig. 2). High demand for limited carbohydrate and nutrients reserves (as CWC stimulates here) decreases fruit set [Breen et al. 2015, Stanley 2016]. These superior results for fruit set in Weak-CWC might be addressed on tree nutritional status (especially nitrogen) accumulated in the previous year. Soil fertilization in the current season has not a much effect on fruit set [Millard 1996].

Strong-CWC had a relatively high cumulative TCSA increase value without significant differences from other CWC levels (fig. 3).

In general, annual TCSA increase negatively correlated with annual yield (crop load) (tab. 2). Crop load governs transpiration, nutrition as well as growth of trees under typical Mediterranean climatic conditions (hot and dry summers) [Wünsche et al. 2000, Bustan et al. 2016, Serra et al. 2016].

Table 2. Pairwise correlations among trunk cross-sectional area (TCSA) increase and yield over 4 years (2010–2013)

Variable	by Variable	Correlation	*P*
TCSA increase in 2010	Yield in 2010	–0.1886	0.4394
TCSA increase in 2011	Yield in 2011	–0.0944	0.6922
TCSA increase in 2012	Yield in 2012	0.4062	0.0755
TCSA increase in 2013	Yield in 2013	–0.1232	0.6263

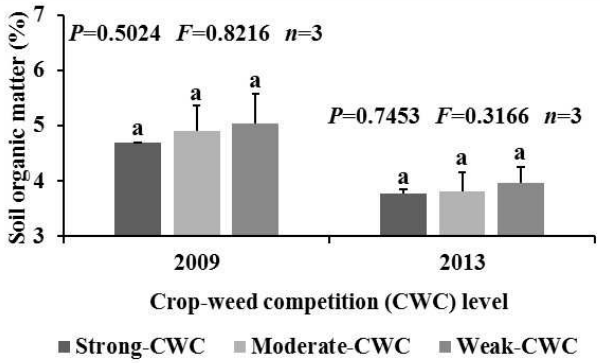

Fig. 4. Effect of crop-weed competition level on soil organic matter at the beginning and the end of the experimental period. The values shown are means ± SD

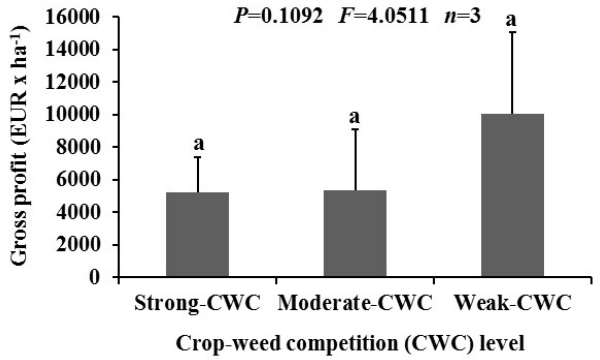

Fig. 5. Effect of crop-weed competition level on the gross profit of 'Golden Delicious'/M.9 apple. The values shown are means ± SD

CWC level did not significantly alter soil organic matter at the beginning (2009), and end of the study (2013) (fig. 4). Soil organic matter was less in 2013 than in 2009 in all CWC levels. It is possible that mowed weeds could not penetrate into the soil while the organic matter oxidation was continued during the study. However, to obtain significant results for the dynamics of organic matter in the soil, a longer experimentation would be necessary.

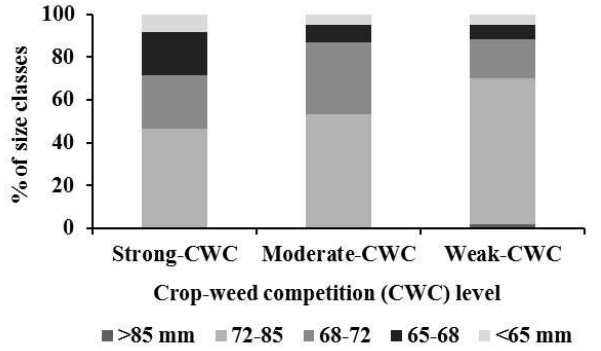

Fig. 6. Percent contribution of each size class to the total yield of each crop-weed competition level. Data for % of size classes, collected in 2012 and 2013, are pooled to create the figure above

Gross profit was relatively high in Weak-CWC, followed by Moderate-CWC and Strong-CWC, respectively (fig. 5). No weed management strategy can be considered without economic return [Granatstein et al. 2010]. An ideal CWC would be an aid to the economic success of fruit growers [Merwin 2003]. This relatively low gross profit in Strong-CWC might be due to smaller fruit size (fig. 6). Thus, in the study region, the price of fruit in 65–68 mm size class is lower than bigger fruit for 'Golden Delicious', and the fruit with <65 mm size are considered culls that are far cheaper than others.

CONCLUSIONS

In conclusion, the competition for resources between weeds and fruit trees in high-density apple orchards affected not only yield but also the gross

profit. To sum up, data suggest that cumulative yield and gross income decrease as weed competition increases, which appeared to be associated with interactions between tree nutritional status, fruit set, vegetative growth and fruit quality.

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REFERENCES

Atay, E., Guzel, P., Gargin, S., Esitken, A., Senyurt, H., Atay, A.N., Altindal, M., Calhan, Ö. (2013a). Determination of important parameters for weed control in intensive apple orchards: weed species and its density. IOBC/WPRS Bull., 91, 439–442.

Atay, A.N., Koyuncu, F., Atay, E. (2013b). Relative susceptibility of selected apple cultivars to alternate bearing. J. Biol. Environ. Sci., 7(20), 81–86.

Bissels, S., Donath, T.W., Hölzel, N., Otte, A. (2006). Effects of different mowing regimes on seedling recruitment in alluvial grasslands. Basic Appl. Ecol., 7, 433–442.

Breen, K.C., Tustin, D.S., Palmer, J.W., Close, D.C. (2015). Method of manipulating floral bud density affects fruit set responses in apple. Sci. Hort., 197, 244–253.

Bustan, A., Dag, A., Yermiyahu, U., Erel, R., Presnov, E., Agam, N., Kool, D., Iwema, J., Zipori, I., Ben-Gal, A. (2016). Fruit load governs transpiration of olive trees. Tree Physiol., 36(3), 380–391.

Gut, D., Barben, E., Riesen, W. (1996). Critical period for weed competition in apple orchards: preliminary results. Acta Hortic., 422, 273–278.

Granatstein, D., Wiman, M., Kirby, E., Mullinix, K. (2010). Sustainability trade-offs in organic orchard floor management. Acta Hortic., 873, 115–122.

http://www.gulbudak.com.tr/en/

http://www.jmp.com/software/

Kim, B.S., Gu, M., Cho, K.C., Yun, B.K., Jung, S.K., Choi, H.S. (2015). Soil physicochemical properties, tree growth, and fruit production in a non-astringent organic persimmon (*Diospyros* × *kaki* Thunb.) orchard affected by mowing frequency. J. Hortic. Sci. Biotech. 90(6), 664–670.

Lauri, P.E., Terouanne, E., Lespinasse, J.M. (1996). Quantitative analysis of relationships between inflorescence size, bearing-axis size and fruit-set-an apple tree case study. Ann. Bot., 77, 277–286.

Merwin, I.A., Ray, J.A. (1997). Spatial and temporal factors in weed interference with newly planted apple trees. HortScience, 32, 633–637.

Merwin, I.A. (2003). Orchard-floor management systems. In: Apples: botany, production and uses, Ferree, D.C., Warrington, I.J. (eds). CABI Publishing, Cambridge, USA, pp. 303–318.

Millard, P. (1996). Ecophysiology of internal cycling of nitrogen for tree growth. J. Plant Nutr. Soil Sci., 159, 1–10.

Serra, S., Leisso, R., Giordani, L., Kalcsits, L., Musacchi, S. (2016). Crop load influences fruit quality, nutritional balance, and return bloom in 'Honeycrisp' apple. HortScience, 51(3), 236–244.

Smith, H.W., Weldon, M. (1940). A comparison of some methods for the determination of soil organic matter. Proc. – Soil Sci. Soc. Am., 5, 177–182.

Stanley, J. (2016). Factors affecting fruit set and fruit quality along branch units of different apricot cultivars, New Zeal. J. Crop Hortic. Sci., 44(3), 171–191.

Tworkoski, T.J., Glenn, D.M. (2010). Long-term effects of managed grass competition and two pruning methods on growth and yield of peach trees. Sci. Hortic., 126, 130–137.

Wünsche, J.N., Greer, D.H., Palmer, J.W. (2000). Effects of crop load on fruiting and gas-exchange characteristics of 'Braeburn'/M.26 apple trees at full canopy. J. Am. Soc. Hortic. Sci., 125, 93–99.