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Effect of soil moisture on temperate fruit crops: A review

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Abstract
Water is the most important input for fruit production. It is required by the fruit plants throughout their life for different physiological processes. Water influences cell division, cell enlargement, respiration, absorption, translocation and utilization of mineral nutrients besides other physiological processes. Optimizing water applications by scheduling irrigation to fruit orchards may increase water productivity, reduce production costs, and increase tree growth and fruit yield.

Keywords: Soil moisture, growth, water relations, nutrient uptake

Introduction
Water forms over 90 per cent of the plant body on fresh weight basis. Water is a constituent of protoplasm and helps to maintain the turgidity of cell wall. Plants can synthesis food only in the presence of water in their system through photosynthesis. It is also a mean of thermal regulation of temperature inside the plants. Organic constituents of the plants such as carbohydrates, proteins, nucleic acid and enzymes are denatured in the absence of soil moisture. Insufficient water supply may result in reduced tree growth, yield and fruit quality due to water stress. Excessive irrigation, on the other hand, may increase nutrient leaching, water-logging problems, incidence of pests and diseases and the associated cost of frequent operation and maintenance of the irrigation system. Thus through the optimum use of water, performance of plants can be improved manifolds. Some work has been done by different researchers on the influence of soil moisture on plant growth, fruit yield and quality, stomatal conductance, transpiration, proline, ABA and carbohydrates contents and uptake of major nutrients in temperate fruits more particularly in stone fruits which is reviewed as under.

Plant growth and vigour: Soil moisture affect plant growth and development by modifying the morphological, physiological and biochemical characteristics of plant. Water deficit or stress interferes with cell division and reduces stem elongation and enlargement of leaves. Largest trunk growth in almond was achieved with fortnightly irrigation during the growing season (Uriu *et al.,* 1969) [80]. Torrecillas *et al.* (1989) [16] observed reduced tree size with driest irrigation treatment in 3-year old Garrigues almonds. Fouad *et al.* (1994) [20] also reported that stem diameter, net increase of total leaf area per plant and net increase of plant dry weight were negatively correlated with water stress in bitter almond seedlings. Irrigation improved growth in peach (Rogers, 1965; Feldstein and Childers, 1965; Tan and Buttery, 1982; Storchus and Kosykh, 1983; Lishchuk *et al.,* 1988; Li *et al.,* 1990a; Rana *et al.,* 1997a) [60, 18, 73, 70, 34, 31, 57], plum (Singh, 1978; Treder *et al.*, 1995) [78, 79] and apricot (Marangoni *et al.*, 1988; Nawar and Ezz, 1993a; Malik *et al.*, 1994) [39, 86, 36, 46]. The soil moisture content below 60 per cent of field capacity and also excessively high soil moisture content reduces peach tree growth (Vavra, 1969) [81]. Similarly, Storchous (1986) [69] noted increased shoot growth and trunk girth of peach trees when irrigated at 60, 70 or 80 per cent of field capacity. Increased shoot growth in apricot trees was observed by Vavra (1966) [82] when soil moisture at 30 cm depth was maintained at 80 to 90 per cent of field capacity. However, Veihmeyer (1972) [83] found that wide differences in soil moisture content above permanent wilting point had a little effect on apricot tree growth. Root growth and weight are also influenced by soil moisture. Abrisqueta *et al.* (1994) [1] observed that, in almond, root growth was favoured in more heavily watered treatment than in less watered treatment. Roots were more dense ir' irrigated than in unirrigated apricot trees (Govi *et al.*, 1996) [24]. Treder *et al.* (1998) [79] reported that irrigation significantly increased the shoot growth of plum cv.

Valor 3-years after planting and trunk cross-sectional area from second year after planting. Sharma and Joolka (2002) [64] observed that plants of almond cultivar Non Pareil irrigated at lower soil moisture tension had superior growth and vigour than those irrigated at higher soil moisture tension. Neilsen *et al.* (2014) [48] reported that the frequency of irrigation had a significant effect on trunk cross-sectional area and higher on trunk cross-sectional area was recorded with high frequency irrigation than with low frequency irrigation in Sweet cherry.

Fruit yield and quality: Improved yield and fruit size with the application of irrigation water in peaches has been observed by many workers (Piaget *et al.*, 1976; Reeder *et al.*, 1976; Albuquerque *et al.*, 1981; Sozzi *et al.*, 1981; Testoni *et al.*, 1982; Cepicka and Novotny, 1991; Crisosto *et al.*, 1994; Bignami *et al.*, 1995; Mannini *et al.*, 1996; Rana *et al.*, 1997b) [54, 59, 2, 68, 9, 75, 37, 58]. Torrecillas *et al.* (1989) [16] observed reduced almond yield with water stress while per cent kernel and kernel size were not affected with the amount of water applied. Texas almond irrigated periodically between June and September had lower fruit sucrose, reducing sugar and starch content (Niedu *et al.*, 1989) [49]. Buchanan and Harrison (1974) [8] stressed the need to irrigate the peaches at 50 per cent of soil moisture level for obtaining maximum yield. However, Haulik (1979) [25] and Storchus and Kosykh (1983) [70] reported improved yield by irrigating peach trees at 80 per cent of field capacity. Whereas, Storchous (1986) [69] reported higher weight and size of peach fruits with irrigation at 60 and 70 per cent of field capacity though, sugar, acid and vitamin C contents remained unaffected. He also observed 2-3 fold increase in productivity over a 3 years period of irrigation. However, Vavra (1969) [81] could not observe any effect of irrigation, on dry matter, sugar and acid contents of peach fruits. Santa Rosa plum irrigated at 75 per cent of field capacity had higher yield, increased fruit size and weight (Singh, 1978) [67]. Drip irrigated plum trees at -0.02 MPa soil moisture tension had higher yield of quality fruits (Treder *et al.*, 1995) [78]. Higher yield of quality apricot fruits with irrigation has also been reported by Marangoni *et al.* (1988) [39]. Garjugin (1964) obtained 50 to 60, 60 to 80 and 90 to 100 per cent increase in yield of plums, cherries and apricots respectively, by irrigating the trees at the rate of 1,500 m^3/ha in winter combined with normal irrigation in the vegetative period. Treder *et al*. (1998) [79] reported that irrigation significantly increased the yield of plum trees and also increased the attractiveness of fruits compared to control. Early water stress decreased the fruit size attained in peach by the end of the reproductive cell division stage and at harvest (Girona *et al.*, 2004; Goldhamer *et al*., 2002) [22, 23]. Deficit irrigation during both the reproductive cell division and the pit hardening stages decreased fruit size at the end of pit hardening stage but a significant fruit size recovery was apparent after the water stress was relieved during the final growth stage (Torrecillas *et al.*, 2000) [76]. Yldrm *et al*. (2012) [88] observed highest yield at higher than 30 per cent of soil wetted area in drip irrigated Kutahya sour cherry grafted on mahaleb seedling while there was no significant effect on fruit weight. Verma and Bhandari (2000) [84] reported that 17-irrigations each of 40 mm depth to be applied at 10-15 days interval during summer and at 20 days interval during winter were optimal for obtaining higher fruit yield along with good fruit quality of peaches grown in north India. Sharma and Joolka (2001) [62] recorded increased fruit set, fruit retension, green almond yield and superior fruit and kernel characters in Non Pareil almond plants irrigated at -0.5 bar than those which were rainfed.

Photosynthesis: Irrigation improved the rate of photosynthesis in peach (Syrbu *et al.* 1983; Li *et al.*, 1990b; Layne *et al.*, 1994) [72, 32, 29]. Similarly, Natali *et al.* (1996) [45] observed higher assimilation rates in Maycrest peach and Maria nectarine when irrigated after harvest with 50 per cent of evapotranspiration than at 75 or 100 per cent. On the other hand, Basiouny (1977) [5] observed lower photosynthetic rate in six-month-old peach seedlings grown under -0.7 bar water stress. Tan and Buttery (1982) [73] recorded reduced photosynthesis upto 17 per cent when 50 per cent of the roots were subjected to stress by withholding water in Siberian C peach seedlings. In cherry also, Flore *et al.* (1985) [19] reported that soil moisture stress decreases photosynthesis. Sharma *et al.* (2007) [65] recorded higher rate of photosynthesis in leaves of Non Pareil almond plants irrigated at -0.5 bar than those plants which were rainfed.

Stomatal conductance and transpiration: Water stress has a pronounced effect on stomatal conductance and transpiration rate. Water stress reduced stomatal conductance in almond (Costel and Fereres, 1982) [12] and peach (Xiloyannis *et al.*, 1986) [86]. Similarly, in peaches, stomatal resistance has been observed to increase with soil moisture deficit (Basiouny, 1977; Punthakey *et al.*, 1984; Layne *et al.* 1994) [5, 55, 29]. Soil moisture stress reduced both stomatal conductance and transpiration in peaches (Tan and Buttery, 1982; Li *et al.*, 1990b; Cheng *et al.*, 1996) [73, 32] and in Methley plum (Andersen *et al.*, 1995) [3]. Dettori (1985) [16] noted reduced stomatal resistance and transpiration rate per unit of leaf area with decreasing water availability in almond, peach and pixy plum seedlings. In apricots, Ruggiero (1991) [61] observed greater stress for stomatal resistance in non-irrigated plants. Leaf transpiration was higher in wet than dry treatments in almond (Torrecillas *et al.*, 1989) [77] and peaches (Punthakey *et al.*, 1984; Lishchuk *et al.*, 1988; Li *et al.*, 1990a) [55, 34, 31]. Tauares and Ferreira (1994) [74] observed more than 20 per cent decrease in relative transpiration with decrease in pre-dawn leaf water potential below -0.4 MPa. He further observed that after 20 days of no irrigation, transpiration decreased by more than 50 per cent. Natali *et al.* (1996) [23] also recorded higher transpiration rate in Maycrest peach and Maria nectarine when irrigated after harvest at 50 per cent of evapotranspiration. Miletic *et al.* (2003) [42] observed a positive correlation between soil moisture content and total water in leaves of plum. Sharma *et al.* (2004) recorded higher stomatal conductance and transpiration rate in the leaves of Non Pareil almond plants irrigated at -0.5 bar than those which were rainfed.

Proline content: Under stress conditions, there is significant accumulation of proline in plants (Waldren and Teare, 1974; McMichael and Elmore, 1977) [85, 40] and in Starking Delicious apple (Chandel and Chauhan, 1991) [10]. Proline, being the most stable amino acid, accumulated during stress and perform a function of storing carbon and nitrogen without damaging the cell (Palfi *et al.*, 1974) [51]. Palfi (1971) [52] noted that under water stress conditions, the free proline increased sharply in the leaves and this increase was more in drought resistant varieties. The accumulation of free proline under water stress significantly increased the amount of bound water in the leaves (Palfi *et al.*, 1974) [51]. Sharma and Joolka (2003) [64] recorded higher leaf proline content in Non

Pareil almond plants irrigated at higher water stress than those irrigated at lower water stress.

Abscisic acid content: Accumulation of abscisic acid (ABA) has been reported at the advent of water stress in many plants (Loveys and During, 1984). Abscisic acid has been shown to control the water balance under drought (Hiron and Wright, 1973) [27], mainly via controlling stomatal closure (Kriedemann *et al.,* 1972) [28]. Pustovoitova (1975) [56] reported that during initial stages of drought, growth inhibitor (ABA) accumulated in the leaves of plum and apricot and there was a significant reduction in auxin content. Xiloyannis *et al.* (1980) [87] suggested that water stress was responsible for increasing the ABA concentration in peach trees. They further observed that leaves of irrigated trees had ABA content in the range of 30-80 ug/g on fresh weight basis. Genkel *et al.* (1982) [21] subjected different fruit trees to water stress conditions and observed that stress for six hours resulted in the accumulation of ABA in plum and peach leaves, whereas, there was no ABA accumulation in cherry leaves. However, by extending the stress conditions for another two hours resulted in higher accumulation of ABA in all the three fruit crops. In irrigated and non-irrigated apple seedlings, Davies and Lakso (1978) [15] noted that ABA levels in leaves increased linearly in response to changes in leaf turgor. Similarly, Chandel and Chauhan (1991) [10] observed increased leaf ABA content with increasing water stress in Starking Delicious apple. Yoon (1995) [89], in Fuji apples, reported that reduction in available water results in the production of chemical signals such as abscisic acid. Sharma and Joolka (2003) [64] recorded higher leaf abscisic acid content in Non Pareil almond plants irrigated at higher water stress than those irrigated at lower water stress.

Carbohydrate content: Water stress produce important qualitative as well as quantitative changes in carbohydrates. Sum total of carbohydrates during summer and autumn was always lower in irrigated than in non-irrigated almond plants (Suslova, 1941) [41]. Carbohydrate metabolism increased under higher soil moisture levels in peach (Docev, 1968) [17]. Decreasing soil moisture caused increase in soluble sugars, decrease in total carbohydrate and starch contents in apricot leaves (Nawar and Ezz, 1993a) [46], increase in soluble carbohydrates in cherry plum leaves (Lishchuk, 1975) [33]. Similarly, increase in nonstructural carbohydrate content in peach seedlings (Basiouny, 1977) [5] and decrease in carbohydrate content in apple (Chandel and Chauhan, 1991) [10] under water stress conditions have been observed. Sharma and Joolka (2003) [64] recorded higher leaf total carbohydrates content in Non Pareil almond plants irrigated at lower water stress than those irrigated at higher water stress.

Nutrient uptake: Adequate soil moisture is necessary for the movement and uptake of mineral nutrition by plant roots. As the soil dries, the movement of nutrients to the root is inhibited both by the less movement along the soil particles and the reduction of mass flow due to lower rate of transpiration as a result of stomatal closure. Work done on the effect of soil moisture on macro-nutrient uptake is reviewed as under.

Nitrogen: Water stress reduced leaf N content in peach (Davidyuk *et al., 1972;* Docev, 1968) [14, 17] and apricot (Branton *et al.,* 1961) [7]. Baccino Giannetto and Garcia Petillo (1995) [4] reported increased leaf N in peach with irrigation. However, Miculka (1983) [41] observed reduced leaf N with drip or channel irrigation in peaches. Morris *et al.* (1961) [44] also reported that in peaches, frequent irrigation decreased the per cent leaf N content. Similarly, in peach and plum trees, 72 hours of waterlogging reduced N uptake (Pasrija and Chitkara, 1988) [53]. In Santa Rosa plum, Singh (1978) [67] could not find any marked difference in the uptake of N when irrigation was given at 25, 50 and 75 per cent of field capacity. Miyake *et al.* (2002) [43] recorded decreased nitrogen content in leaves of *Prunus mume* Nanko because of soil dryness during summer. Sharma *et al.* (2007) [65] recorded higher leaf nitrogen content in Non Pareil almond plants irrigated at -0.5 bar than those plants which were rainfed.

Phosphorus: Leaf P content is also influenced by soil moisture levels. There was a progressive decline in peach leaf P concentration with a decrease in soil water content from 70 to 10 per cent of the total available water capacity of the soil (Hibbard and Nour, 1959) [26]. However, Singh (1978) [67] could not find any marked difference in P uptake with irrigation at 25, 50 and 75 per cent of the field capacity. Higher accumulation of P in peach tree tissues with high soil moisture levels was reported by Docev (1968) [17]. Leaf P content increased with irrigation in peach (Baccino Giannetto and Garcia Petillo, 1995) [4] and apricot (Branton *et al.*, 1961) [7]. But P uptake reduced with 72 hours of waterlogging in peach and plum trees (Pasrija and Chitkara, 1988) [53]. Similarly, non-irrigated or stress conditions reduced P concentration in apricot (Nawar and Ezz, 1993b) [47]. Sharma *et al.* (2007) [65] recorded higher leaf phosphorus content in Non Pareil almond plants irrigated at -0.5 bar than those plants which were rainfed.

Potassium: Potassium concentration was found to be higher in peach trees grown under lower soil water suction (Hibbard and Nour, 1959; Morris *et al.*, 1961; Docev, 1968; Baccino Giannetto and Garcia Petillo, 1995) [26, 17, 44, 4]. However, in peach and plum trees, after 72 hours of waterlogging, there was reduced K uptake (Pasrija and Chitkara, 1988) [53]. K content also reduced with lesser amount of irrigation in Santa Rosa plum (Singh, 1978) [67] or under water stress in apricot (Branton *et al.*, 1961; Nawar and Ezz, 1993b) [7, 47]. Sharma *et al.* (2007) [65] recorded higher leaf potassium content in Non Pareil almond plants irrigated at -0.5 bar than those plants which were rainfed.

Calcium: Irrigation increased leaf Ca content in peach (Miculka, 1983) [41]. Water stress conditions reduced leaf Ca content in apricot (Nawar and Ezz, 1993b) [47] and apple (Chandel, 1989; Nielsen and Stevenson, 1986) [11]. However, Marangoni and Rossipisa (1985) [38], found that leaf Ca contents were similar in irrigated and non-irrigated apple trees. But Lehova and Doichev (1983) [30] observed reduction in leaf Ca content of Golden Delicious apples under reduced soil moisture. Sharma *et al.* (2007) [65] recorded higher leaf calcium content in Non Pareil almond plants irrigated at -0.5 bar than those plants which were rainfed.

Magnesium: Water stress has been reported to reduce leaf Mg content in peach (Miculka, 1983) [41] and apricot (Nawar and Ezz, 1993b) [47]. Whereas, Branton *et al.* (1961) [7] found the lowest Mg content in apricot leaves in the irrigated plots. But, Morris *et al.* (1961) [44] could not find any difference in leaf Mg concentration between irrigated and non-irrigated peach plants. Sharma *et al.* (2007) [65] recorded higher leaf

magnesium content in Non Pareil almond plants irrigated at -0.5 bar than those plants which were rainfed.
From the above review it can be concluded that optimum soil moisture improves the plant growth, fruit yield, quality and other physiological activities as well as nutrient uptake in different temperate fruit crops. Thus irrigation water should be applied judiciously.

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