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Safe Methods for Weed Control in Fruit Crops: Challenges, and Opportunities: Review

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ABSTRACT

Weed management is an important component in fruit crop production. The current review is (1) a meta analyses of the literature on the yield losses of fruit crops by weeds, (2) it comprises the databases of weed species and density, the period of weed competition, safe weed management in the fruit crops in terms of adverse effects of weeds on the soil, growth, nutrient statutes and productivity of fruit trees, advantages and disadvantages of weed control measures, and (3) it excluded the cover crops, biological weed control, natural herbicides and non-traditional weed control methods as well as small fruit crops such as blueberry, blackberries, raspberries and strawberry. The ranges of yield losses in fruit cropsdue to weeds observed from the literature were varied widely from 23.7% to 82% and in some instances of weed infestation;there wasno production of fruits with commercial value obtained. The yield lossdepends on weed speciesand its densityand fruit crop species.So, weed management in fruit crops is necessary to prevent or reduce yield losses and the search for more effective and environmentally friendly approaches forweed control will be needed. Acombined approach could result in an effective weed control technology.

Keywords: cultivar, intercropping, mulch, polyculture, organic farming, yield loss

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INTRODUCTION

In the world, there are many fruit crops, including evergreen trees such as palm, citrus, olive, banana, mango and others, and deciduous trees such as figs, pomegranates, grapes, peach, apple, almonds, pears, apricots, and others. Fruit trees are a major source of agricultural income in the world.

Organic tree fruit production continues to expand in a number of regions in response to steady increases in consumer demand for organic fruit [1]. However the price of fruits from organic farming is higher than that of the conventional farming, there is noestablished price premiums for the organic raisin [2].

Weed presence in fruit crop orchids leads to cut the number and weight of fruits/tree and consequently reduce the yield by and fruit quality.

To estimate the losses caused by weeds in the orchids it must be taking into account the decrease in the amount and quality of the crop, the cost of control operations, and nutrient and water losses.

This paper aimed to review on the current non-chemical weed control methods in fruit tree crops, the weed infestation, critical period, losses in tree productivity and fruit quality knowledge also highlighted.We excluded the cover crops, small fruit crops such as blueberry, blackberries and raspberries, strawberry (in Egypt this crops

consider a vegetable crops), biological weed control,natural herbicides and non-traditional weed control methods. Most reviews concentrate on chemical weedcontrol or only on fruit tree species (citrus, walnut orchards, stone fruits etc).

In the light of the environmental and toxicological problems created by herbicides such as polluting, nontarget toxicity, long-persistence, carcinogenic and mutagenic activities, it has become necessary to utilize the safety methods for controlling weeds. We depended on the numerous previous published studies and our research articles of weed impacts on fruit crop productivity.

1. Magnitude of weed problems in fruit crops

Weed pressure caused a reduction in the tree growth by about 15 to 96% [3], while the loss in fruit yield reached to 35% as a result of the adverse impact on fruit quality, reaching the fruits excluded ratio to 45%. In the stone trees, the yield reduction reached to 50% [4]. It has been spotted more damage from the presence of weeds in orchards and small peach age of 4 years, where he found that leaving weeds without control resulted in the death of 29% of the young peach tree and reduced trunk diameter by 62% and the decrements in number and yield of fruits amounted by 73 and 75%, respectively [5].

To image the weeds seriousness; it was found in one hectare of orange groves have 12.6 to 17.1 tons ha^{-1} of weeds (fresh weight) after 30 and 60 days of hoeing [6], while, in peach [7] and apple [8] orchards, the weeds fresh weight of the weeds were 15.2-18.7 and 5.96 tons ha^{-1}, respectively. In banana crop the dry equivalent weight of weeds reached 3.6 tons ha^{-1}[24]. In California vineyards, weed seeds per acre was estimated by 40 million weed seeds [9].

The harmful of weeds not related to the abundance of their number but to its biomass [10]. It's expected that the weeds will increase by 30% due to the increase of CO_2 rates in the atmosphere due to global climate change [11].

Unfortunately the majority of weeds that appear in the fruit orchards belong to World's Worst Weeds depending on the classification [12], which is characterized by grow in many countries of the world, and reproductive by more one way, and need for more way to control them, and difficult to eradicate, if left for of time without control.

2. Weed species and density in fruit crop groves

The weed density in fruit orchards varied according to the crop grown, soil, irrigation and fertilization systems, grove age, season, the soil type, and the history of the agricultural practices in orchard [13], it reached 49% in citrus groves [14], while in mango was 42% [15].

Indifferent orchards in Egypt cultivated with *Citrus spp.*, the total number of weed species was 169 related to 126 genera and grouped under 35 families. Out of these weeds, 47 species were monocots (27.8%) and 122 species were dicots (72.2%). Gramineae and Composite were the main families representing collectively about 36.1% of the total recorded species[16]. They added that the perennial, biennial and annual weed species were 29.58%, 2.37% 68.05%, respectively. While [17] found 130 weed species belonging to 42families, and most of these weeds pertained to Poaceae family and were perennial in citrus groves. Also, in citrus grove, it was showed more 200 species of weeds [18].

In olive grove, it was found more than 80 weed species belonging to 14 families dominated by Poaceae, Fabaceae, Asteraceae, Ranunculaceae and Rosaceae [19, 20]. While in another study, monitoring 92 species of common weeds in olive grove belong to 29 families and the families of Poaceae, Fabaceae, Asteraceae, Ranunculaceae and Papaveraceae, Rosaceae constitute of 48.7, 18.2, 10.8, 7.3, 3.4%, respectively [21].

In apple orchard, the total weed species was 69 , and most of weed plants present in strips next to roots, a total of 58 weed species and 48 species in inter-rows [22] and mallow (*Malva spp*.) ranked as the main weed problem [23].

In banana plantations, it was recorded more than 93 weed species belonging to 37 families, including 60 annual weeds and 27 perennial weeds and 6 weeds between the annual and perennialand 50% of these weeds have medicinal value [24]. The reduction in the tree productivity due to weed competition may be attributed to that some fruit crops such as pineapple related to the Crassulacean Acid Metabolism (CAM), plants group, which is characterized by the opening of the stomata during the night and closing them during the day. As a result, this species grows slowly, being less aggressive and less competitive with weeds [25].

In general, from the literature review, it could be concluded that the dominantweeds in the fruit orchards are a broadleaved weeds grow in the winter such as *Medicago hispida, Chenopodium album, Rumex dentatus, Melilotus indica, Capsella bursa-pastoris, Malvaparviflora, Coronopus squamatus, Sisymbrium irio, Sonchus oleraceus,*

Emex spinosus, Sinapis arvensis, Urticaurens, Vicia sativa and *Cichorium pumilum*. While the winter narrowleaved weeds are *Phalaris minor, Polypogonm onspeliensis, Lolium sp., Avena fatua*. In summer season, the common broadleaved weeds are *Amaranthus retroflexus, Portulaca oleraceus, Solanum nigrum, Sida alba, Euphorbia prunifolia, Xanthium pungens, Hibisicu strionum, Datura quereifolia* and *Conyza aegyptiaca*. While, the summer narrowleaved weeds are *Dactyloctenium aegyptium, Echinochloa colonum Fork, Cenchrus pennisetiformis, Brachiaria eruciformis* and *Dinebra retroflexa*.

Perennial weeds that grow in orchids, including perennial narrowleaved weeds, such as *Cynodon dactylon, Panicum coloratum, Cyperus rotundus, C. esculentus, C. longus, Phragmites australis* and *Imperata cylindrica*. While the most dominant perennial broadleaved weeds are *Convolvulus arvensis* and *Alhagi maurorum medic*.

Worthy to mention that weeds does not appear in the drip irrigation system except in the wet areas only and this sometimes be more harmful to the fruit tree as a result of weeds concentration above the root zone [26], but the benefit comes more the result of reducing the spread of weeds space making it easy with fewer herbicides amount used [27], with time the developing weeds in wet area will be located under the shade of trees which decreases light to the weeds then inhibition of growth will be occurs and particularly those weeds related to C_4 plants such as sedges and many grass, where the dicots weeds are more sensitive to the light than monocots [28].

It was noted that two-thirds of the weeds in olive groves, monocots, while the rest are dicots weeds [21]. On the contrary, it was found in mango orchards about 241 thousand weeds, 90.6% of which are broadleaved and 9.4% only monocots [15].

3. Loss in fruit yield due to weeds

Un-controlling the weeds in orchids cause severe damage to the soil, trees health, their nutrient statues and productivity. We could monitor some losses in orchids as follows:

3.1. Reduce soil temperature: the extensive weed infestation in the orchard during the winter season, lead to reduced soil temperature by about 2-4 ºF (colder) [13] leading to the creation of cold damage compared to that weed-free. Low soil temperatures due to the presence of weeds in fruit orchards adversely affect the nutrient absorption.

3.2. Water loss: the percentage of moisture in the soil pineapple orchard 17.2% in the case of non-weed control versus 33.4% at weed control [29].

1.1. **Increase the production cost**: weed control management in orchids expensive process and represent a significant proportion of the total production costs, it was estimated the cost of weed control in citrus groves by 24.4% [30], while in banana was 50% of the total cost of production [31].

3.3. Influence on the trees growth: It has been found that the weed infestation reduce trunk diameter, leaves weight and metabolism [32], and decrease the annual growth rate of apple by 25% [33], while the branches length was increased 1.4-1.6 times when weed control was conducted [10]. Weed interference, including vole damage, caused 29% peach tree mortality and reduced tree trunk cross-sectional area by 62% at the fourth year of orchard establishment[5].

The less leaf area index in grape trees was observed as a result of weed competition.Leaf chlorophyll andthe fresh weight of peach trees (Fig.1) were reduced in peach (*Prunus persica* L. 'Norman') trees in the presence of all densities of common bermudagrass [*Cynodon dactylon* (L.) Pers.] [34].

The reduction in tree growth and productivity due to weeds may be attributed to their allelopathy effect, where [35] reported that the weeds infest tree fruit with allelopathic potential were quackgrass, yellow nutsedge and common lambsquarters.

In a mixed population with two species, the smaller plant might benefit from CO_2 enrichment to a great extent than the larger plant because of light interception properties, which would give weeds a competitive advantage [36]. The physiological plasticity of weeds and their high degree of intraspecific genetic variation could provide weeds with a competitive advantage in a changing environment [37]. The reduction in tree growth and productivity may be attributed to the allelopathic effects of weeds on fruit trees [38].

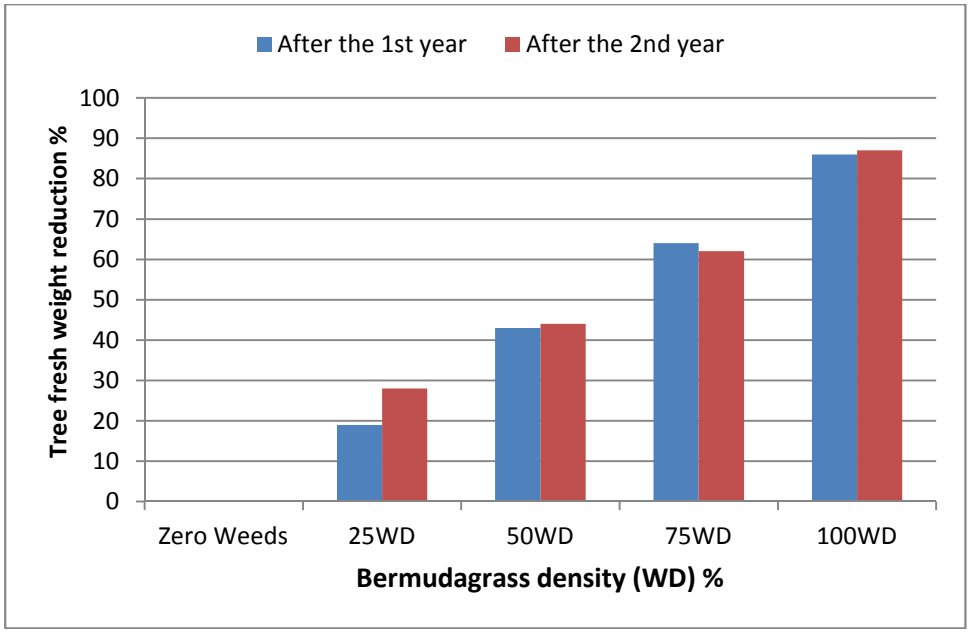

Fig. 1: The effect of common bermudagrass density on the fresh weight of peach trees [34]

3.4. Nutrient deficiency: most fruit trees absorb most nutrients by its roots occupied the surface soil layer and this is one of the reasons why fruit trees influenced by the presence of weeds although the trees have great trunk and large vegetative growth. it was found a reduction in the NPK concentrations of grapes leaves by 2.3, 4.0 and 20.3% respectively as a result of weed interference [39], while, controlling the weeds, mainly *Chenopodium album*, in citrus trees has led to a reduction in the losses amount of nitrogen and zinc from 133.5, 2.0 to 29.0 – 50.2 kg ha^{-1} and from 0.16 to 0.77 kg ha^{-1}, respectively [40], and oblivious increase in the nutrient statues of the leaves of Navel oranges [41]and on guava (*Psidium guajava* L.) [42] due to weed control. A highly competitive effect of weeds for K with young pecan trees, and weed competition also suppressed leaf Ca and Mg, but the presence of weeds resulted in higher soil pH and leaf Zn were found [43]. On the contrary, they added that N, P, B, Cu and Fe concentrates in the leaf were not significantly affected by weed presence. Also, it was mentioned that weed control did not have any significant effect on the nutritional status of the grape vines as measured by nutrient levels of the leaf petiole tissues [44].

3.5. Competition for light, air and water: some weeds such as vines, Field bindweed (*Convolvulus arvensis*) compete the trees on light where shaded and covered it until they from prevent them light and so the trees not complete the photosynthesis process.

3.6. Reduction of tree productivity: weed competition or high presence of the weeds in orchids leads to cut the number and weight of fruits/tree, yield and fruit quality. Weed interference, including vole damage, reduced fruit yield and fruit number by 73 and 75%, respectively, but had no effect on fruit size [19]. The highest flower drop (36.8%) in guava plant was noted in the unweeded control, and thus, highest fruit set (82.97%) was recorded in weeded control compared with only 48.66 % observed in control [43].

In some cases of weed competition there was no production of fruits with commercial value obtained as in pineapple grove [45]. While weed control in olive groves increased their fruit and oil yield by 50 and 63%, respectively,as a result of increased fruit weight compared to unweed [19].

Datain Table (1) indicates to the decrement percentages in the productivity of some fruit trees as a result of non-weed control. The amount of loss in fruit production varied according to the dominant weed in the orchard, whereValencia orange crop has declined by 78% when the *Cynodon dactylon* is the dominant weed, while the loss was 57% in the presence of annual weeds [18].

Table 1:Yield loss of some fruit trees as a result of weed competition

Crop	Yieldlosses (%)	Reference	Crop	Yield losses (%)	Reference
Olive	33.4	[19]	Grape	29.1-45.2	[39]
Peache	31.8	[7]	Apple	36.2-42.0	[8]
Navel orange	23.7-61.7	[41, 46]	Banana	50.8	49
Mandariene	62	[47]	Stone fruits	50	[4]
Citrus	50-77	[18,48]	Pineapple	82.7- 88.0	[14]

3.7. Negetive impact on the chemical constituents and the fruit quality: weed competition causes a negetive impact on some fruit qualy, such as weight and fruit diameter, the thickness of the crust, total soluble solids, and the percentage of total acidity, total sugars and vitamin C in fruits [42]. However, fruit color, set, maturity, and percent soluble solids were unaffected by weed control methods studied [50].

3.8. Host to insects: groves must be from the weeds because they are hosts for the fruit fly, and the weed free help the farmer to follow-up drop fruits that attracked by insects. Itwas found a relationship between the presence of *Thrips hawaiiensis* insect and the presence of weedsin mango orchards [51].

3.9. Host to diseases and nematodes: The weeds considere host for certain diseases and nematodes, it was reported that more than 45 of weeds showed in orchards such as slender amaranth, sicklepod, balsam apple, purple bushbean, little ironweed, ivy gourd, cutleaf groundcherry are hosts to the nematode [52], and that the *Commelina diffusa*weed is the host of the root-knot nematode, which cause serious damage to banana trees [24].

4. Cost of weed control in orchids

Weed control in orchids are expensive and cause a heavy burden on the fruit producer, especially in organic farming [53].The costs of weed control include the cost of the machine, chemical material, worker's wage and fuel used. The cost of weed control in banana groves has reached about 50% of the total costs [16]. In Florida, the total annual losses in citrus due to weeds were estimated at $60 million that included $12-15 million for herbicides and related materials and $28-30 million for mechanical tillage, mowing and other operations [54].

Weed control accounts about 10% [55] to 24% of the total production costs in citrus [56]. Weed control equivalent to about 30-40% of the total cost and therefore it represents the largest component in the cost of fruit crops [15], while [13] estimated it in citrus grove by about 225.11 $/acre, which represents 14.3% of the total costs.

Mulch was a one-time expense that cost US$2.969 per hectare (US$1.202 per acre), nearly ten times the annual cost of tillage, but mulch gave efficient weed control for 2-4 years and likely provides growth benefits beyond that for the trees. The mulch material itself represented three quarters of the cost especially with a long transportation while if there is no transportation, this cost would have been less. One quarter of the cost was incurred from the application of such a large amount of bulk material using a rented mulch spreader [1]**.**

Mulching produced a large net economic benefit relative to tillage, more so in the apple orchard that had sandier soil than in the pear orchard on a loam soil [1].

Concerning the organic herbicide costs, it was estimated by US$ 509 per acre when the rate and concentration were raised to levels that provided some degree of weed control. Regardless of herbicide product, weed control with these organic-compliant herbicides was expensive and marginally effective [1].

5. The Critical Period for Weed Control in fruit crops

The productivity of fruit trees is strongly influenced by weed competition; therefore, the estimation of the critical period of weed competition is very important for planning weed control strategies in orchards. The weed control in fruit groves process throughout the years are expensive process, and because the fruit trees can tolerant the weed competition for a period during the year and during its life, but there are a sensitive period of control practices to the fruit trees, the trees may be affected adversely by mechanical or chemical weed control. So, we must know the critical period of weed control in fruit orchard to control the weeds at adjust time and in order to save expenses and prevent any yield losses.

The critical period of weed competition in fruit crops is varied according to the age and type of fruit and plant density, the weed species and its density, the irrigation system, fertilization and soil fertility.

In pecan (*Cary aillinoinensis* Wangenh. C. Koch) groves, trunk diameters were suppressed 54% when the weeds not controlled, 47% when not controlled until 1 Aug., and 37% if not controlled after 1 June compared to entire weed

control. Trunk diameters were not significantly different from entire season weed control, when weeds were controlled from 1 June through fall frost or weeds controlled from April until 1 Aug. so, weed control in the entire season may not be essential to obtain maximum growth of pecan [57].

Grape plants are more sensitive to the weed competition at the 3-4 the first year [58]. While, the critical period of weed competition for Zinfandel grape occurs during bud break-bloom period[49].

In pineapple grove, weed control performed after floral differentiation did not increase the size; neither improved the quality of the fruit [45].

For peach crop it was found that the critical period for weed control 12 weeks after peach tree bloom, and weed control in that period gave the highest weight and diameter of the fruit and the highest number and yield of fruits and prolonged the period of control after 12 weeks from tree bloom had insignificant impact on peach crop [59].

In a New York apple (*Malus domestica* Borkh. cv. Imperial Gala on Malling 26 rootstocks) orchard, [27] examined 28 factorial treatment combinations i.e. 4weed-free areas WFAs (0-6 m^2); and 7 weed-free times (WFTs)] were maintained for 5 years. They found that a few differences were observed as WFA increased from 2 to 4 to 6 m^2 per tree. However,WFTs substantially influenced Trunk cross-sectional area (TCA), fruit production, and yield efficiency. Early summer WFTs increased TCA during the first two growing seasons, compared with late summer treatments. Yields increased as the duration of WFT increased, but where similar periods of WFT had been established later during the growing season, annual yield, cumulative yield efficiency, and the ratio of crop value to weed-control costs were all reduced. They concluded that in apples a 60–90 day weed-free period from May to July provided the best growth in apples [27].

In banana, the weed control must beginning since planting for a period of 30 months after planting, and the narrowleaved weeds must controlled if the grassy density reached to 10-20% of the soil surface and when the grasses height is up more than 6 inches [60].

In grape crops, the plants adversely affected by the presence of weeds in the first 3-4 years and un-controlling the weeds in this period will delay the growth of the vines and reduces its productivity. After this period, the roots of vines become bigger and stronger and the vegetative growth will become vigorous and shade the ground which adversely affects the growth of weeds and cut weed competition with vines [58].

Generally, some fruit trees need only to weed control in small area around the trunk and after that is not affected by the presence of weeds. For example, dwarf apple and semi-dwarf trees need weed control at a distance of 2-4 feet around the trunk of the tree, and outside this area the trees is not affected by the presence of weeds [61].

6. The importance of weed control in fruit crops

Weed control achieved in orchids several benefits including:

6.1. Increase the yield quantity and quality: weed control in the orchids increases the tree productivity as a result of increasing the number and weight of fruits per tree [47]. The aim of weed control in fruit groves is suppress the weed growth or prevent weed competition during the critical period of crop growth to maximization the productivity of fruit trees. It’s difficult to evacuation the orchard floor from the weeds (although there are many fruit groves completely free of weeds), the important thing is to reduce the weed density to the level that does not cause any adverse effect on fruit trees to produce the highest yield. Using maize straw mulch in banana grove resulted in 18-27% in yield [62], whilerice straw mulchincreased fruit yield (50%) and oil yield (63%) of olive crop [19].Data in Fig. (2) shows the increase in the yield of mandarin trees due to weed control methods [46].Weed control in banana plantations led to an increase of bunch weight by 21.1% as a result of increase growth banana plants [63]. In absence of the weeds, Valencia orange tree,under sprinkler irrigation, gave 66.9 kg, while the yield of the tree in the presence of annual weeds or *Cynodon dactylon* gave only 28.7 and 0.15 kg, respectively [48].

6.2. Increase the efficiency of agricultural practices, i.e. fertilization, irrigating and harvesting.
6.3. Reduce losses from disease and insects: some weeds act as ahost of insects, nematodes and diseases [52].
6.4. Reduce the risk of fire.
6.5. Minimize the effects of frost on trees

7. Methods of weed control in fruit orchards

There are several methods of weed control in fruit orchards, i.e. mechanical, chemical, physical, agricultural methods, biological methods and the introduce methods that may appropriate to the nature and size of the growth of fruit trees. Each weed control method has some advantages and disadvantages. Therefore, it's not goodto rely on one

way to control the weeds, and the best is the integrated weed control, which relies on the use of more than a means taking into account the role of other agricultural operations in pest control.

Weed management in fruit crops should favour primary values such as the safety of people and the environment, including the quality of soil, and should take into account the effectiveness, costs, and influence on yielding of the cultivated crops [64].

Worthy to mention that in any weed control system must take into account the short-term and long-term effects of this method on the agricultural ecosystem in orchards.

Non-Chemical Weed Control Methods in Fruit Crops

The trend of organic production for local consumption or export is increasing day by day, in order to avoid the harmful effects of pesticides which are not allowed to be use in organic farming due to environmental problems that have accompanied to the use of synthetic herbicides. In Poland, reported that from 26 herbicides authorized or recommended for use in fruit crops, they found that 11 of them are very toxic, 4 of toxic, and 5 of unhealthy [10]. On the contrary, it was rumored that organic farming is more harmful to the environment, more expensive and give half the production of conventional farming and this is not true [65]**.**They found that apple trees gave equal productivity under three systems of production methods, a traditional agriculture, organic, and integrated farming. Both organic farming and integrated crop management have a positive impact in improving the soil and less negative environmental impact than the traditional system. Also, they found that these two systems produced apple fruits with high sweetness, a high rate of profitability due to higher prices of fruit-producing in organic farming because there is more than 50% in price from their counterparts, and increasing energy efficiency as compared with conventional systems. Some researchers found that organic farming give between 50-95% productivity compared to conventional agriculture [66]. In America with using the alternative methods to chemical, they reduced the amount of chemical pesticides used in pecan by 35% [67]. The famous herbicide in the world, Roundup® (a glyphosate-based herbicide), might lead to excessive extracellular glutamate levels andconsequently to glutamate excitotoxicity and oxidative stress in rat hippocampus excitotoxicity [68].

Moreover, it has been suggested important associations betweenthe bulk sale of pesticides and the increased rates of several types ofcancer, endocrine disorders and a high prevalence of neurodegen-erative diseases in agricultural workers, providing a link between glyphosate and Parkinson's disease [69] and might lead to excessive extracellular glutamate levels and consequently to glutamate excitotoxicity and oxidative stress in rat hippocampus [68]. In USA, the major economic and environmental losses due to the application of pesticides were: public health, ($1.1 billion year); pesticide resistance in pests ($1.5 billion); crop losses caused by pesticides ($1.4 billion); bird losses due to pesticides ($2.2 billion) and groundwater contamination ($2.0 billion) [70].

Therefore, alternative methods to herbicides such as Integrated Fruit Production (IFP) and Integrated Pest Management (IPM) offer an economical and high quality of fruit production framework, giving priority to ecologically safer methods, minimizing the undesirable side effects and use of agrochemicals, and enhancing the safeguard of the environment and human health.

7.1. Mechanical Weed Control

Mechanical weeding is, by far, the most immediately applicable method for weed management when the use of chemicals is undesirable [71]. There are some mechanical control methods used for controlling the weeds in orchards floor such as hand weeding, hand hoeing, mechanical cultivation, weed trimming, mowing (mechanically or chemically), each method have some advantages and disadvantages.

A- Manual hand weeding and hand hoeing: two of the oldest methods of control and the most effective and safe for humans and the environment. However, its efficiency 100% weed control, this methods do not use now because itsvery labor, time consuming, expensive and there are another cheap methods [72].The most common management for weed control in organic orchards is tillage in the weed strip. It is relatively inexpensive but can negatively impact tree performance and soil quality [73], difficult and require many labors [26], and due to its high cost and the lack of workers its used only in small area of the groves, especially in the case of certain perennial weeds such as *Convolvules arvensis* or weeds adjacent to the trees. It has been observed in some orchards that depending on mechanical control are abound with annual weeds more than perennial weeds [74].

Almost of the apricot (*Prunus armeniaca* L. *cv*. Búlida) root system was located in the first 0.75 m of soil depth, with 91% in the first 0.50 m. More than 75% of the roots corresponded to thin roots, with a diameter less than 0.2 mm [75], thus it must take into account the depth of mechanical hoeing withnature of the trees roots.

B- Mechanical cultivation

There are several machines uses for cultivation in orchards floor which save time and cost. Some constraint faces the use of machines in fruit crops such as growing some fruit trees as temporary crop between main crop trees such as citrus trees intercropping with mango or mango and citrus fruit with olives. In addition, many of these machines cultivate between rows and leave the weeds under the trees; so the cultivation must be in the two directions.

Disadvantages of mechanical weed control

I. Ineffective methods for controlling the perennial weeds *i.e*. bermudagrass, nutsedges, phragmites *etc* [13].
II. Sometimes automated hoeing lead to death of some fruit trees, it has been found that the use of plow-disc has led to the death of 19% of the peach trees in a 4 years period [76], and in apples by 10% [77], while the herbicides not caused this death.
III. Lead to an increase of some perennial weeds as shown in Photo (1), and cultivation in the two directions does not fit inthe high density of trees (the narrow distance betweentrees orbetweenrows) [13].

The underground organs (i.e. tubers, stolons, rhizomes and creeping root systems) perennial weeds such as sedges, *Cynodon dactylon*, cogongrass and *Phragmites* etc. capable of forming new shoots (form at depthswhich vary from species to species [71] making it difficult to control after that. However, in olive groves where tillage comprises a common practice, annual weed species are more prominent than perennial ones [74]. Also, automated hoeing may breaks branches and make cuts in the trunk, especially in the case of a dense weeds close to the trunk of the trees, which cause the infection with plant diseases [78].

IV. Lead to increase the incidence of fruit trees by plant diseases, where *Pythium* root rot was more prevalent in peach [*Prunus persica* (L.) Batsch] orchards where roots were damaged by cultivation [79].
V. Cultivation may reduce the number and mass of tree roots and this will led to a 42% decline in root growth and cause long -term yield loss and slower tree growth, while the straw mulched trees had a 40% increase in root length [80].

7.2. Soil mulching

Mulch is considered the alternative safe weed control method to herbicides in fruit orchards. It began with the beginning of agriculture itself since ancient times, and the mulch word is Germany in origin i.e. the soft and prefix material to decomposition and decay. From 1802 use of the mulch, terminology used worldwide [81]. Mulches defined as any material covered the soil surface and have the ability to survive as a cover around the plants to prevent the weed growth and prevent soil erosion [82].

Mulch materials may nonsynthetic material or maybe synthetic mulch. Plant waste such as straw of rice, barley wheat, corn and wheat straw (in some countries, such as Egypt, the wheat straw has a high price because it is use for animal feeding) or the paper used, and some aquatic weed can be used an nonsynthetic mulch or a biodegradable mulch in fruit orchards [46] and they can be tilled in by the end of the season, thus resulting in reduction of the labour cost for weed suppression [83]. Synthetic mulch materials such as plastics (polyethylene) with different colors, fiber, acrylic, propylene, Geotextile and fabric mulches, weed fabrics, etc. Some of these materials are expensive (1000$/acre) and some such as weed fabrics can be used in nonbearing trees for 4-5 years at least, after that it is not practically can't use in fruit trees bearing orchards because harvesting operations will be lead to destroyed it. Tarp edges were buried 2 inches in the ground to hold it in place.

Almost all mulches except polyethylene film are bad conductors of heat. They get heated up on receiving short-wave solar radiation, but transmission or conduction of heat is very less [84]. They prevent sunlight from reaching to soil covered by it and to germinating weeds, whose photosynthesis inhibited causing them to die. They also provide an effective barrier to weed emergence. Even the germinated weeds, find it difficult to penetrate the thick layer of mulch. The relative cost of mulching, especially compared with chemical weed control, and concern over rodent damage to trees [85].

Mulches reduce weed seed germination by blocking light and prevent seedling emergence on the soil surface providing a physical barrier for the emerging weeds [19].

Major causes of mulch deterioration were unnecessary walking on the mulch during drip irrigation installation and planting and the careless handling of equipment while moving, digging tree holes, and cultivating. When emitters discharged water on the plastic mulch rather than on the tree hole due to shifting by pipe contraction water failed to reach tree roots [86].

The advantages of mulch in orchards include:

a. ***Weed control****:* Good tree growth and excellent weed control were obtained with the plastic mulch in newly planted avocado, mango, and papaya groves [87] as shown in Photo (1). Soil mulching is very effective against most

annual weeds and some perennial weeds such as *Cynodon dactylon*, *Sorghum halepense*. The greatest control (94%-100%) of weeds was occurred with the plastic mulch (200 or 150 µm) and three mulch layers of rice straw or cattail. Covering soil with cattail or rice straw mulch (two layers) gave 85%-98% control of weeds [46]. In olive groves, among the non-chemical treatments, the straw mulches in three years provided the greatest grass and total weed suppression, which ranged from 74 to 94% and 89 to 95%, respectively [19]. In avocado grove, soil mulching at 15 cm mulch depth resulted in the greatest reduction in weeds, but even the 2.5 cm depth had some effect [87]. For avoiding the synthetic herbicides problems, mulching was a very good alternative method to herbicide use and the best results of weed control were obtained with saw dust, coarse bark and hay mulches where they exhibited 99.4, 99.3 and 96 % weed control, respectively [88].

Photo 1: high density of sedges between citrustree rows after repeated cultivations (left) and soil mulch in papaya grove (right)

b. ***Increasing the tree growth****:* An important effect of mulches on root architecture of avocado was an increase in root length and spatial distribution in avocado, which was not found in citrus. This change in rooting pattern may partially be responsible for improved disease resistance in avocado, but there was no difference in canopy volume in either lemon, orange or avocado trees [87]. Banana plants were larger in mulched than in unmulched systems with yield advantages of 18–27% [62].

c. ***Conservation of soil water***: In mandarin (*Citrus reticulata* Blanco) grove, [89] found that the soil-moisture conservation was higher under black polyethylene 100 µ (4.33%) mulch, followed by grass mulching (3.0%). Straw mulch reduced annual water use by 4.6 and 15.8% over a period of 2 yr and wheat straw mulch lowered irrigation water use by 9.7% relative to herbicide treatment[90]. In apple grove using wood chips as mulch in apple grove led to 20%- 30% savingsin irrigation water [53]. Applications of 4 to 6 inches of wheat straw mulch around the fruit trees caused a reduction in the weed growth, reduces water needs by 20% and adds organic matter to the soil as it decomposes mulch generally have to improved the drip irrigation efficiency [91].

d. *Increasing fruit trees productivity (quantity and quality):* In mandarin (*Citrus reticulata* Blanco) grove, [89] covering the orchard floor by black plastic 100 microns thickness, straw of soybean or rice or local grass (at a rate of 3 tons ha^{-1}) and found that the tallest trees, the largest trunk diameter and shoots size, harvest, the highest fruit weight and fruits yield per tree, total soluble solids acidity and the percentage of Juice content (49.9%) were recorded in the case of the soil surface covered by black plastic, followed by grass mulch. The highest fruit and oil yield were produced by the olive trees in plots treated with the straw mulches (30.5 and 6.7 kg per tree, respectively. The greatest mean fruit weight was observed in trees located in plots treated with the straw mulches (2.8 g) [19].

Plastic mulches of 200 and 150 µm, cattail (*Cyprus articulatus* L.) mulch (2 or 3 layers) and two mulch layers of rice (*Oryza sativa* L.) straw treatments significantly increased the fruit yield/tree by 24%, 18%, 20%, 11%, and 12% more than cultivation treatment, respectively, without significant differences among these superior treatments [47] as shown in Fig (2).

However, mulches did not have a positive effect on total soluble solids of the apples fruit and the number of fruits in different size categories. Only sawdust mulch significantly increased the number of fruit in size diameter class of 7.0–7.5 cm compared with the control [93].

e. ***Improving the orchard floor soil properties***

Mulched treatments produced over three times more biomass than bare soil treatments. This increase in biomass was likely due to improved fertility as a result of mulching, since mulched treatments had higher concentrations of soil organic C, P, and exchangeable K and Mg, and foliar K. Mulchedbanana took up more water from both the 0- to 0.3-m and 0.3- to 0.5-m depths than banana grown without mulch and soil water recharged more quickly in the

mulched treatments as a result of increased porosity from 0- to 0.3-m depth [92]. The pH and organic matter content of the soil in apple grove were positively affected by using mulches of rye straw, pine bark, conifer tree sawdust, compost (plant debris), cow manure or peat moss substrate. The best results were observed with the use of the compost, cow manure, where the concentrations of P, K and Mg, most of microelements and soil organic matter were elevated [93].

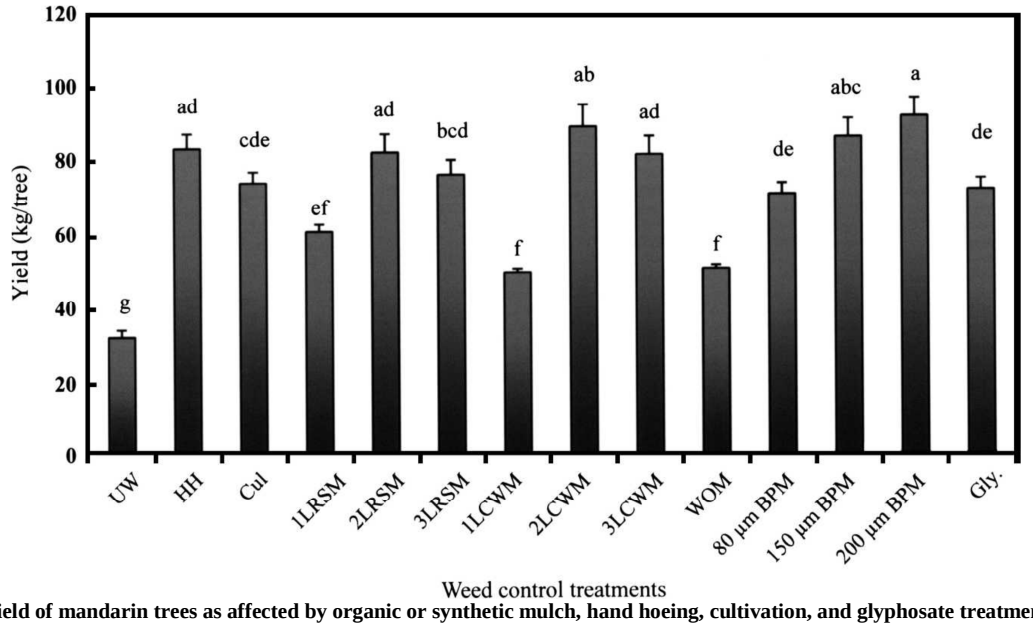

Fig. 2: Yield of mandarin trees as affected by organic or synthetic mulch, hand hoeing, cultivation, and glyphosate treatments. Bars labeled with the same letter are not significantly different (P = 0.05, Student–Newman–Keuls) probability. UW: unweeded, HH: hand hoeing, Cul: cultivation, LRSM: layer of rice straw mulch, LCWM: layer of cattail weed mulch, WOM: wild oat mulch, BPM: black plastic mulch, Gly: glyphosate [47]

f. ***Control of pests***

Mulchingmay mitigate the impact of nematodes on bananas when applied to low fertility systems [92], reducing the citrus nematode *Tylenchulus semipenetrans* larvae in both soil and roots [94].

Disadvantages of mulch on fruit crops

a. Increased number of some pests:Banana weevil populations were higher in mulched than in unmulched systems [63]**.** They conclude that mulching is beneficial for banana production, but that there are no banana weevil management advantages to mulching away from the base of the banana mat. Also, number of banana weevil *Cosmopolites sordidus* (Germar) was increased by 37-44% as a result of water[90].Banana weevil populations to be up to 2.5 times higher in mulched than in unmulched plots [95], and they added that yield losses to banana weevil to average 3.4 ton ha^{-1} $crop^{-1}$ cycle in mulched banana fields compared to 1.8 ton $ha^{-1}$$crop^{-1}$ cycle in unmulched plots.Root disease caused by *Phytophthora spp*. and depredation by meadow voles(*Microtus pennsylvanicum*)were increased under soil mulch of apple tree [17]. This increment of diseases maybe attributed to the improved moisture conservation under mulched which suitable for disease growth especially in the dry seasons and soils.

b. Hay mulching were very expensive because of the hand labor involved [86].

c. Straw mulch in apple orchards led to a substantial increase in young tree mortality as a result of crown rot (*Phytophthora cactorum*) [17, 53].

d. Blackgeotextile fabric led to a decline in soil quality and tree performance relative to other mulches. This was, in part, the result of elevated soil temperatures under the fabric (up to 10 ºC) [52, 96].

e. Theroots of the trees under mulch treatment become superficial and thus affected by wind and any defect of water or nutrients.

f. Source of weed seeds: Straw is effective at preventing weed growth; however,introducing weed seeds with the straw is an added risk [80].

Effect of type, colour and thickness of mulchon the weed controlefficiency and trees productivity:

There many different materials usedin mulch. It may be organic such as plant wastes, straw of canola, wheat, rice and banana leaves, sawdust, anygreen vegetable wastes, water hyacinth or synthetic mulch such as polypropylene, etc. or any available materials with low price and can prevent weed growth. Weed reductions in apple orchards were as high as 99.4% with saw dust, 99.3% with coarse bark and 96.0% with hay [88].

Straw was applied at a 15 cm thickness and wood chips were applied to a thickness of 6 cm [80]. Concerning the polyethylene colours it was found that using black polyethylene as a mulch in orchards gave the highest weed control efficacy than that of green, blue, yellow and white[8].

In citrus groves, the highest weed control efficacy was obtained with black plastic mulch 150 and 200mm thickness, rice straw mulch 9 cm thick and cattail (*Cyprus articulatus*, L.) weed mulch at 12 cm deep [47].They noticed that insignificant effect between 8 and 12 cm deep of cattail mulch on weeds.

Some growers prefer to use organic mulch than plastic materials, because the organic materials decompose and add organic materials to the soil and thus improve the soil properties and water conservation, but it is need to repeat the addition every 2 years and take high cost transport [97]. Where some growers reached the amount of organic mulch to 150 tons from chips of limbs and leaves of eucalyptus *(Eucalyptus robusta*) plant per hectare in the lemon grove (*Citrus aurantifolia*) [98]. Average weed coverage (%) was found 56.09% in control (weedy), 3.09% in black polyethylene, 2.78% in geotextile -50, 0.87% geotextile -100 and 0.76% geotextile-150, respectively [99].

It could be conclude that using plant wastes mulch is consider safe weed control method in fruit crops and this technique will eliminate the hazards of herbicides, and improve the soil fertility and save water.

7.3. Plant Density

Fruit crops are perennials and it remains for a long time, thusit's difficult to change the plant density after some years from plantation. Therefore, it's better to adjust the optimum density at the planting. A plant density one of the weed control measure in the integrated weed management in orchards and increasing the plant density, especially in the row will be result to shade the floor surface faster and thus will limit the growth of weeds. Also, planting the dwarf or semi-dwarf species or grafting on dwarf rootstocks which grown in high density as Gloster species in apple, is considered one of the integrated methods of weed control in orchids [100].

7.4. Row Orientation

However, *Solanum nigrum* weed is strongly affected by light in greenhouse tests, but did not show a clear effect of the direction of the grapes rows (East-West) on the growth ofgrapes, however, there are improved in the growth and productivity of grapes compared to the direction of the rows from north to south [101], where the weeds and grape plants exposed to more light by 80% compared to the other direction. Also, the weed density was varied in the vineyards depending on the method of vertical breeding such as T, V, Y, or any other method of breeding [26].

7.5. Cultivar selectivity

The fruit crop varieties are varied in the weed density, weed species associated it. It was found an obvious variation in the numbers, fresh and dry weight of weeds species and weight between two mango varieties. In Saigon variety it was found 9 weed species (weed density 21.5% with a total number of 658 weeds) while in the Edward variety it was found 16 weed species (weed density and the weed number were 41% and 1230, respectively). This results show the importance of the varieties' role in weed control [15]. Therefore, fast-growing varieties must cultivated on a wide distances, because it will grow faster than dwarf varieties and shading the soil. In the first case is grown 50-80 tree/acre while dwarf tree 200 to 1500 trees $acre^{-1}$. Also, it was reported that the yield losses due to weeds was reduced in the case of fast-growing varieties as in case of both apples varieties i.e. Gloster and Melrose (the both were grafted on M9). While the yield losses in medium-growing variety (Idared/M9) reached to 30% [18] to 45% [102]. It was also noted that the orange trees grafted on vigorous root stocks can't tolerant the weed competition compared to that the trees grafted on a slower growing root stocks. Thus, the critical period for weed competition of Valencia orange trees grafted on *Cleopatra mandarin* are not equal with those grafted on *Carrizo citrange*. Therefore, the yield of two varieties is different because it will influence by the presence of weeds [18]. Also, grape varieties are varied in their sensitivity to the selective and non-selective herbicides [103].

In another study, it was found that orchardgrass reduced vertical water sprout length of 8-year-old peach [*Prunus persica* (L.) Batsch.] trees by 15 % to 27% and lateral shoot length on fruit-bearing branches by 19% to 30%. Orchardgrass reduced yield of two cultivars (Loring and Redhaven) of peach trees by 37 % and 24 %, respectively [104].

7.6. Cultivation of temporary crops

Some growers cultivate, during the early ages of fruit trees and before the spread of tree roots,some temporary crops, such as potatoes, tomatoes, eggplant, tato [*Colocasia esculenta* (L.) schott], zucchini, peppers, and prefer legumes such as beans, peanuts, peas, clover and lupine plants. These temporary annual crops have ahigh cash net and needed higher amount of nutrients and thus improve the soil fertility [105, 106].

Growing single or double crops of cowpea in banana grove gave 65.7% weed control efficiency, better banana plant growth, 21.1% more bunch weight and benefit: cost ratio was also higher as compare to control [63].

Disadvantages of growing temporary crops in fruit orchards

a) Some Cucurbitaceae plants such as watermelon, cucumber and squash may be source of diseases such as powdery mildew to the fruit trees.

b) Cultivating near the tree, damages the feeder roots that are close to the soil surface which can decrease tree performance. Cultivation is the least expensive organically approved weed control in orchards. Straw is effective at preventing weed growth; however, introducing weed seeds with the straw is an added risk [80].

7.7. Intercropping or multiple cropping and polyculture

Intercropping is known to suppress weeds and pests, because of the higher biodiversity in comparison to monoculture. Interplanting papayas in mango grove decreased costs of weed control. Hay mulching also required equipment to load, unload, and transport the hay [86]. Intercropping of haricot bean was found as good intercrop for pineapple and gave high yield when integrated with hand weeding and mulching [14].

Growing of double crop of cowpea with banana and its incorporation in soil recorded 65.7% weed control efficiency, better plant growth, 21.1% more bunch weight and benefit: cost ratio was also higher as compare to control. It can be concluded that growing of double crops of cowpea and its incorporation in soil can be followed for effective management of weeds [62].

Some farmers grow two types of fruit trees together in the same area of groves, which is known interplanting orpolyculture.

The most common intercropping of fruit crops is growing citrus trees as temporary between the main crop mango trees or, where citrus is fast growing trees and gave earlier yield compared to mango trees. Also, some growers planting mango with date palm [106]. This method leads to increase the shaded area of the orchard floors with trees and cause a limitation in the weeds growth. There are some problems related to this intercropping; such as low growth rate of mango trees compared to monoculture and the water regime needed for mango in certain period, which unsuitable for citrus trees, but it's suitable in the case of polyculture mango with palms. Otherwise, some of the trees must be removed when they start to crowd each other. Therefore, there a tendency toward mono fruit crops. Intercropping of papaya with avocado or mango led to good results of weed suppressions, decreased costs of weed control and increased the income [87]. Reference [107] summarized the literature and reported that intercropping banana with cowpeas, corn, sweet potatoes and peanut could significantly suppress weed infestations. They added that there was an increase in bananayield when intercropped with corn compared to pure stands in trials conducted and this was probably due to adequate fertilization of both crops.

After revision the literature on intercropping, it was reported that the fruit crops are usually intercropped with annual crops [108]. They mentioned some actual application such as banana is intercropped with food and/orfodder crops to increase and use efficiency for smallholder farms, banana with sweet potato and beans; bananas with potato or mustard, citrus mandarin seedlings and cucumber. They also mentioned that in Kenya fruit trees are intercropped with all types of short term crops such as beans, peas, potatoes, maize, millet,exotic and indigenous vegetables when they are still young as a way of attaining food security and income before the trees mature. They also mentioned that when banana was intercropped with three densities of *Grevilla robusta* of 208, 313 and 0.25 trees per hectare, it was found that after 3.5 years thewood volume of *G. obusta* was highest while banana and bean yields in the intercrop system were unaffected. In Egypt some farmers growing citrus as temporary crops in mango, and cultivated berseem, potatoes, wheat, vegetable leaves.

The benefits of Intercropping or multiple cropping and polyculture with fruit trees

a. Decrease weed and pest population: reduced the incidence of *Striga hermontheca* and reduce the incidence of weevils and nematodes [107, 108], and decrease the cost of weed control [87].

b. Increase the net return [87,106].

c. Increased land equivalent ratio [108].

7.8. Hot-steam method

Hot-steam technology when applied at 1 km h^{-1} driving speed, in 7 day intervals in apple grove had less control efficacy on the perennial weeds, and the repetition the treatment for higher reduction of vigorous weeds and for the longer time effect are inevitable [88].

7.9. Other nonchemical weed control methods

There are another some alternative weed control methods to herbicides are use for weed control in orchards which reduced the abundance of weed species ranged from 60 to 100% such as cover crop [109], natural herbicides**,** flame weeding, biological control, and new and nontraditional weed control methods such as Electrical Weed Control, Electromagnetic Waves, Fresnel Lens, Hot Steaming, Hot Water, Hyperspectral Species Identification and Thermal Micro-Dosing, Microwave Radiation, Ultra Sonic Weed Control Systems, Pneumatic Weed Control, Precision Guidance Technology (GPS), Radiation Infrared, Soil Steaming, Superheated Steam, Water Cutting, Ultraviolet Light, Lasers and Autonomous Robotic Weed Control Systems. These techniques have potential application to some extent to control the weeds in the absence of herbicides**.**

Therefore, it is essential to test newly developed safe methods to weed control, and to carry out extensive field studies in a large range of conditions that lead to minimize the weed infestation and increase the fruit crops productivity.A combined approach could result in an effective weed control technology.

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