Asian Journal of Plant Sciences

ISSN 1682-3974

science alert

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Asian Journal of Plant Sciences 12 (6-8): 241-246, 2013
ISSN 1682-3974 / DOI: 10.3923/ajps.2013.241.246

Seasonal Changes in Endogenous Plant Hormones and Alternate Bearing of Nabali Olive (*Olea europea* L.) Trees

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Abstract: Alternate bearing is one of the major cultural problems and economic drawbacks particularly in olive groves which is the main fruit tree crop in the Mediterranean area as well as southern Europe. Changes in hormone concentrations might be attributed to alternate bearing habit. Therefore, concentrations of Abscisic Acid (ABA), Indole Acetic Acid (IAA), Gibberellic Acid-like substances (GA) and Kinetin-like Cytokinin were determined and their relationship to flower bud formation was examined during "on" and "off" years. Results showed significant differences in IAA, ABA, GA_3-like and Kinetin-like-Cytokinin between "on" and "off" cropping years in various tissues of olive trees. Relative balances between GA_3-like and an ABA concentration in tissues might be a key regulator of floral development and alternate bearing. Olive growers are advised to do fruit thinning during "on" year crop to reduce the occurrence of this phenomena.

Key words: ABA, GA_3, IAA, Jordan, Nabali

INTRODUCTION

Olives (*Olea europaea* L.) which belong to Moraceae Family are commercially grown throughout the world in areas of Mediterranean climate (Burns *et al*., 2008; Dag *et al*., 2011). In the last few decades, there has been a significant increase in the global consumption of olive oil, even in countries where it is not produced, such as the Canada and Japan (Mili, 2006). This is due in large part to its nutritional and health-promoting effects (Manna *et al*., 1997).

The worldwide surface grown with olive trees amounts to almost 9 million ha (FAOSTAT, 2009). The olive fruits production in Jordan during 2011-2012 was 221 thousand tons. Olive trees cover more than 75% of areas of fruit trees and 'Nabali' is considered as a dominant olive cultivar in Jordan. More than 73% of the planted olive in Jordan is 'Nabali' or its derivatives. Most of olive fruits are used as source of oil while 17% were utilized as naturally ripe olive in brine (MOA, 2012). Alternate bearing is one of the major cultural problems and economic drawbacks. Alternate bearing causes severe economic losses in many of the important olive cultivars. Typical yield loss in commercial plantings in the "off" year is nearly 50% in Jordan according to MOA (2011).

Cultural and environmental factors, such as pruning, drought, inadequate chilling and light intensity, may influence flower bud formation and contribute to alternate bearing (Lavee, 1985). Endogenous phytohormones are key factors controlling alternate bearing physiology. Hartmann (1973) measured both endogenous inhibitors and promoters in olive leaves and buds. Lavee (1985) found more chlorogenic acid in bearing than in nonbearing olive trees. The assumption that chlorogenic acid induced flower bud formation was not supported when application of chlorogenic acid decreased yield. Hartmann (1973) found no difference in auxin concentrations of differentiating and non-differentiating olive buds while Epstein (1981) showed considerably higher levels of bound IAA in leaves of plants with non-differentiated buds. Gibberellins strongly inhibit flowering, although the mechanism by which this occurs is not fully understood (Palese and Crocker, 2002). Alternate bearing in olives results in fewer floral buds being produced in the "on" year trees carrying a heavy crop load than in subsequent "off" year with trees carrying a light fruit load.

The present study was aimed to understand the behavior of olive trees in relation to alternate-bearing phenomena, by following the pattern of abscisic acid (ABA), Gibberellic acid-like substances (GA_3), Indole

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acetic acid (IAA) and Kinetin-like cytokinins in the tissues of 'Nabali' olive trees at three different Jordan locations, in order to understand how to reduce the effect of this phenomenon.

MATERIALS AND METHODS

This study was carried out on 'Nabali' olive cultivar at three different orchard locations in Jordan; the first orchard (Al-Salt) was located at the west side of Jordan (32°01'48.22"N; 35°42'18.35"E), the second orchard (Madaba) was located at the east side of Jordan (31°73'12.25"N; 35°45'54.15"E) and the third orchard (Jerash) was located at the north side of Jordan (32°19'30.77"N; 35°54'36.27"E) and these locations represent the main area of olive planting in Jordan. At each location five-tree plots of each location were replicated four times in a completely randomized block design (RCBD). The selected olive trees were about 12-15 years old, with about 8×8 m between and within rows. Hormonal analysis was conducted on nodes, shoot tips and leaves of the current-season growth along with fruit samples. Samples consisted of 10 g fresh weight of each plant part selected from the periphery of the trees at a height of 1.5 m on each of the four cardinal aspects of the tree. Sampling began in January 2010 and continued at monthly intervals until December 2011. Analysis of ABA, GA-like substances, IAA and kinetin-like cytokinins was determined according to Rivier and Crozier (1987). Samples were homogenized in cold 70% methanol at room temperature and were temporarily stored at 7°C. The extracts were filtered through Whatman No. 5 filter paper and the supernatant was rehomogenized with the same solution and the extracts were combined. The methanol phase was reduced in pressure through a rotary evaporator at 40°C. The aqueous residue was adjusted to pH 8.5 with 1 N NaOH and extracted three times with ethyl acetate; the ethyl acetate phase was then discarded.

The aqueous phase was adjusted to pH 2.5 with 1 N Hcl and extracted 3 times with diethyl ether. The ethyl ether phase was reduced under vacuum. The crude extract was dissolved in 1 mL methanol. Samples of crude extract (100 μL) were applied to TLC plates (Merc Silica Gel 60 F254) and then developed in an 84 misopropyl alcohol: 8 ammonia: 8 water (v/v) solvent. Spots detected under an ultra violet (UV) lamp were scraped from the plates, dissolved in 1 mL HPLC grade methanol and filtered through 45 micropore filters. High-pressure liquids chromatography (HPLC) analysis of the phytohormones was performed by reversed-phase HPLC on a Varian model 9050 (Walnut Creek, Calif.) equipped with a variable wavelength UV detector and autosampler. Separation and determination were conducted using a nucleosil C_{18} (4.6×150 mm i.d.) column. Samples were run at 25°C column temperatures. Columns were eluted with 30% methanol (adjusted to pH 3.0 with 0.1 M H_3PO_4) for GA, 55% methanol in 0.1 M acetic acid for ABA, 35% methanol in 1% acetic acid for IAA and 35% methanol for Kinetin-like cytokinin.

Detection was by a variable wave length UV detector at 208, 265, 280 and 254 nm for GA-like substances, ABA, IAA and kinetin-like cytokinin, respectively. A 20 mL of methanol solution was injected into the analytical columns using an autosampler. The flow rate was 1 m min^{-1}. Phytohormone concentrations (μg g^{-1} fresh weight) were automatically calculated from peak area software using authentic standards run with the samples (Sigma Chemicals, St. Louis).

RESULTS AND DISCUSSION

The physiological process leading to spring flowering begins in the preceding summer as environmental factors initiate the induction process. Flower bud induction in olive may occur as early as July or about 6 weeks after full bloom. Microscopic examination revealed evidence of floral initiation by November but the full development of all flower parts did not occur until March (Ferguson *et al*., 1994). In his review of olive fruit set and development, Lavee (1986) highlighted the report concluding that levels of auxins and cytokinins in olive tissues were considerably lower than those of other fruit trees. In the present experiment, our results indicated low or undetectable levels of phytohormones in various tissues at many times during the year. IAA was detectable only in the leaves and nodes of 'Al-Salt' and 'Madaba' locations during November and December in the "on" year. However, 'Al-Salt' location shoot tips interestingly showed IAA peaks in July with 1.792 μg g^{-1}, in the "on" year while the highest IAA was observed in the shoot tips during December at Jerash location with 0.594 μg g^{-1}, in the "on' year (Table 1).

In general, GA_3-like substance levels in leaf, node and shoot tip samples were higher in the "on" year in comparison to levels in the "off" year. In fruit tissue, GA levels started to rise at fruit set and these levels were maintained until harvest in the "on' year. High GA_3-like concentrations in midsummer (embryo development period) appeared to have a negative influence on generative bud development in favor of vegetative bud formation. Concentrations of GA_3-like substance in all tissues in midsummer, fall and winter prior to the "on" year were at the minimum levels in all three locations.

Table 1: IAA concentration (μg g^{-1} FW) in leaf, node, shoot tip and fruit of 'Nabali' olive trees in different locations in "on" and "off" years of one alternate bearing cycle

	IAA concentration (μg g^{-1} FW)		Months											
Locations	Plant part	On/off year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Jerash	Leaf	On	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.034	0.000	0.000	0.000	0.000
		Off	0.000	0.157	0.146	0.000	0.000	0.000	0.000	0.246	0.000	0.000	0.000	0.023
	Node	On	0.302	0.090	0.067	0.090	0.000	0.000	0.000	0.000	0.000	0.000	0.078	0.000
		Off	0.000	0.000	0.078	0.101	0.078	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Shoot tip	On	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.056	0.594
		Off	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fruit	On	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.191	0.000
AL-Salt	Leaf	On	0.000	0.067	0.000	0.000	0.000	0.000	0.000	0.157	0.078	0.325	0.000	1.501
		Off	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.034	0.000	0.000	0.672
	Node	On	0.392	0.280	0.000	0.000	0.549	0.000	0.000	0.045	0.000	0.000	1.624	2.890
		Off	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Shoot tip	On	0.224	0.000	0.000	0.000	0.000	0.000	1.792	0.000	0.000	0.000	1.333	0.000
		Off	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fruit	On	0.224	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Madaba	Leaf	On	0.000	0.000	0.000	0.370	0.000	0.202	0.000	0.000	0.000	0.000	3.192	0.448
		Off	0.000	0.112	0.000	0.090	0.000	0.101	0.000	0.123	0.000	0.000	0.000	0.000
	Node	On	0.224	0.000	0.000	0.045	0.000	0.067	0.000	0.000	0.000	0.000	2.106	0.280
		Off	0.000	0.000	0.000	0.000	0.034	0.000	0.000	0.000	0.381	0.000	0.000	0.000
	Shoot tip	On	0.336	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.280	0.000
		Off	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fruit	On	0.549	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.482	0.650	0.000	0.000

Table 2: GA_3-like concentration (μg g^{-1} FW) in leaf, node, shoot tip and fruit of 'Nabali' olive trees in three different locations in "on" and "off" years of one alternate bearing cycle

	GA_3-like concentration (μg g^{-1} FW)		Months											
Locations	Plant part	On/off year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Jerash	Leaf	On	4.223	2.419	2.766	0.034	1.590	0.179	0.246	0.448	0.235	1.064	0.437	4.973
		Off	0.202	0.560	0.146	0.974	0.773	1.053	1.680	0.818	0.246	0.022	1.165	0.314
	Node	On	1.165	0.101	0.381	0.450	0.336	0.022	0.101	0.034	0.246	0.034	1.725	1.960
		Off	0.157	0.112	0.067	0.426	0.347	0.202	0.448	1.546	1.322	0.470	0.493	0.101
	Shoot tip	On	0.224	0.101	0.370	0.515	1.008	0.213	0.000	0.034	0.101	0.403	0.907	0.258
		Off	0.045	0.112	0.067	0.504	0.515	0.134	0.067	0.190	0.112	0.717	0.280	0.090
	Fruit	On	0.000	0.000	0.000	0.000	0.762	2.363	1.075	1.086	0.538	0.616	0.963	0.000
AL-Salt	Leaf	On	0.538	0.829	1.310	2.912	0.482	0.560	0.101	0.336	0.370	0.750	0.627	2.554
		Off	0.762	0.347	0.450	1.344	0.302	0.358	1.232	0.470	0.773	1.030	0.403	0.112
	Node	On	2.352	0.761	0.224	0.258	0.762	0.034	0.134	0.022	0.269	0.112	1.949	2.374
		Off	0.571	0.045	0.022	0.717	0.157	0.874	1.232	0.784	1.714	2.139	0.403	0.022
	Shoot tip	On	1.064	2.397	0.605	0.403	0.045	0.157	0.123	0.056	0.157	0.112	1.546	3.797
		Off	0.090	0.941	0.101	0.112	0.784	0.246	0.090	0.627	1.254	0.112	0.213	0.078
	Fruit	On	0.000	0.000	0.000	0.000	1.434	1.579	1.322	0.997	0.403	2.643	0.930	0.168
Madaba	Leaf	On	1.277	1.310	1.344	0.963	0.795	0.235	1.658	1.344	0.112	0.941	0.224	4.032
		Off	0.325	0.134	0.112	0.829	0.202	0.448	0.426	1.142	0.123	0.728	0.011	0.392
	Node	On	1.322	0.202	1.322	0.403	0.627	0.022	0.347	0.045	0.123	0.101	1.971	3.774
		Off	0.224	0.146	0.045	0.246	0.190	0.694	0.907	1.501	2.352	2.027	0.123	0.269
	Shoot tip	On	0.336	0.448	0.291	0.224	0.078	0.022	0.022	0.045	0.246	0.269	0.784	1.030
		Off	0.067	0.067	0.045	0.403	1.019	0.101	0.179	0.571	0.269	0.650	0.011	0.022
	Fruit	On	0.000	0.000	0.000	0.000	0.504	2.195	1.299	1.378	1.098	0.762	0.448	0.000

However, GA_3-like substance levels of all tissues sharply increased after fruit set. The highest GA_3-like substance levels in the fruit-bearing period were found in fruits in June and July and then gradually decreased until December. GA_3 levels also increased in leaves, nodes and shoot tips during this time period but the increases were not as substantial as those in fruit samples. Sequential determinations of gibberellins in developing olive fruits by Shulman and Lavee (1980) showed a gradual reduction in GA content during fruit development, with GA levels at full-black maturation being very low. GA_3-like substance levels in the leaf and node samples were found to be highest in December and January in the "on" and then began to decrease until late spring, then increased again in midsummer (Table 2).

Kinetin-like cytokinin levels, in leaves, nodes and shoot tips in the "on" year were higher than the "off" year. Shulman and Lavee (1976) showed that compared to most other fruits, cytokinin content in olive fruit increases with maturation. However, these levels in winter, spring and summer were statistically significant while the levels were different in fall. Kinetin-like cytokinin in November in the "on" year produced detectable peaks (Table 3).

Table 3: Kinetin-like cytokinin concentration (μg g^{-1} FW) in leaf, node, shoot tip and fruit of 'Nabali' olive trees in three different locations in "on" and "off" years of one alternate bearing cycle

	Cytokinin concentrations (μg g^{-1} FW)		Months											
Locations	Plant part	On/off year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Jerash	Leaf	On	0.403	0.000	0.090	0.090	0.571	0.090	0.101	0.101	0.112	0.034	1.12	0.000
		Off	0.000	0.067	0.302	0.090	0.090	0.045	0.090	0.090	0.056	0.022	0.078	0.022
	Node	On	0.750	0.000	0.123	0.314	0.045	0.045	0.179	0.213	0.168	0.224	1.042	0.571
		Off	0.000	0.146	0.179	0.224	0.414	0.022	0.112	0.134	0.157	0.179	0.067	0.000
	Shoot tip	On	0.000	0.022	0.224	0.045	0.034	0.000	0.213	0.000	0.034	0.033	1.064	0.000
		Off	0.000	0.034	0.112	0.000	0.134	0.000	0.078	0.000	0.034	0.000	0.000	0.000
	Fruit	On	0.000	0.000	0.000	0.000	0.179	0.000	0.134	0.067	0.157	0.078	0.762	0.000
AL-Salt	Leaf	On	0.000	0.000	0.202	0.403	0.000	0.896	0.090	0.045	0.302	0.022	1.501	0.022
		Off	0.022	0.224	0,000	0.090	0.302	0.157	0.000	0.000	0.112	0.000	0.123	0.067
	Node	On	0.538	0.269	1.254	0.302	0.000	0.560	0.213	0.538	0.123	0.000	1.781	0.224
		Off	0.213	0.370	0.000	0.000	0.034	0.146	0.224	0.224	0.414	0.000	0.134	0.000
	Shoot tip	On	0.426	0.224	0.034	0.04	0.157	0.078	0.022	0.000	0.000	0.000	0.706	0.392
		Off	0.000	0.000	0.000	0.000	0.034	0.000	0.034	0.112	0.000	0.000	0.078	0.000
	Fruit	On	0.000	0.000	0.000	0.000	0.078	0.045	0.168	0.717	0.269	0.000	0.627	0.000
Madaba	Leaf	On	0.246	0.112	0.000	0.000	0.157	0.090	0.000	0.078	0.056	0.067	0.336	1.053
		Off	0.000	0.034	0.123	0.179	0.000	0.034	0.034	0.067	0.034	0.000	0.190	0.000
	Node	On	0.067	0.168	0.269	0.134	0.190	0.302	0.022	0.403	0.056	0.090	0.235	3.461
		Off	0.000	0.045	0.067	0.157	0.123	0.000	0.000	0.146	0.034	0.000	0.034	0.000
	Shoot tip	On	0.000	0.090	0.000	0.000	0.146	0.146	0.034	0.045	0.000	0.034	0.997	0.325
		Off	0.000	0.000	0.022	0.034	0.123	0.000	0.000	0.000	0.000	0.000	0.056	0.067
	Fruit	On	0.000	0.000	0.000	0.000	0.090	0.022	0.078	0.190	0.034	0.213	0.896	0.000

Table 4: ABA concentration (μg g^{-1} FW) in leaf, node, shoot tip and fruit of 'Nabali' olive trees in three different locations in "on" and "off" years of one alternate bearing cycle

	ABA concentration (μg g^{-1} FW)		Months											
Locations	Plant part	On/off year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Jerash	Leaf	On	2.710	0.291	0.056	0.101	0.437	0.616	1.075	0.470	2.061	0.314	0.448	1.010
		Off	0.067	0.493	2.486	0.470	0.179	0.202	1.210	0.694	0.123	0.190	1.008	0.370
	Node	On	0.885	0.078	0.112	0.258	0.190	0.370	0.179	0.258	0.526	0.157	0.426	1.086
		Off	1.075	0.336	0.403	0.213	0.426	0.347	0.202	0.773	0.358	0.280	0.101	0.358
	Shoot tip	On	0.291	0.202	0.302	0.392	0.168	0.090	0.246	0.134	0.056	0.00	0.717	0.157
		Off	0.112	0.224	0.538	0.022	0.426	0.101	0.112	0.515	0.045	0.022	0.045	0.123
	Fruit	On	0.000	0.000	0.000	0.000	0.213	0.493	0.594	0.638	0.762	1.378	0.582	0.000
AL-Salt	Leaf	On	0.246	0.034	0.134	0.147	0.358	1.389	1.624	0.515	2.531	0.336	0.392	0.022
		Off	0.034	0.347	1.053	0.235	1.512	0.482	0.672	0.661	2.184	1.680	0.482	0.280
	Node	On	0.773	0.134	0.101	0.056	0.325	0.403	0.538	0.482	1.523	0.336	0.370	1.613
		Off	0.896	0.179	0.358	0.302	0.358	0.403	0.414	0.560	0.986	1.490	0.459	0.246
	Shoot tip	On	0.202	1.456	0.112	0.213	0.235	0.168	0.123	0.112	0.302	0.022	0.739	0.504
		Off	0.045	0.112	0.078	0.112	0.224	0.246	0.381	0.202	1.086	0.190	0.078	0.202
	Fruit	On	0.000	0.000	0.000	0.000	0.314	0.291	0.358	0.560	0.862	1.310	0.403	0.000
Madaba	Leaf	On	1.971	0.907	0.090	0.112	0.414	0.963	1.299	0.638	2.610	0.235	0.414	1.232
		Off	0.056	0.090	0.325	0.168	0.392	0.706	0.302	0.078	1.613	1.445	0.403	0.459
	Node	On	0.437	0.190	0.157	0.123	0.235	0.090	0.571	0.134	1.971	0.280	0.448	1.814
		Off	0.269	0.157	0.381	0.146	0.470	0.246	0.381	0.762	2.050	1.232	0.146	1.590
	Shoot tip	On	1.982	0.045	0.202	0.067	0.224	0.090	0.067	0.101	0.806	0.291	0.672	0.717
		Off	0.157	0.280	0.157	0.235	0.179	0.157	0.683	0.302	0.381	0.112	0.067	0.056
	Fruit	On	0.000	0.000	0.000	0.000	0.269	0.370	0.314	0.426	0.638	3.606	0.269	0.000

ABA concentrations in leaves of the three locations were irregular in both years, with ABA levels being higher in fall. Compared to summer and winter seasons, ABA concentrations in the nodes were almost the same in the fall and winter (between 0.336 and 2.13 μg g^{-1}) and were their minimal levels (0.09 to 0.78 μg g^{-1}) in spring and summer. This pattern is normal for inhibitors. The differences in ABA concentrations between nodes and shoot tips were not statistically significant in both "on" year and "off" year samples. In the nodes, ABA was lower in the spring and summer while levels are higher in fall and winter. ABA concentrations in fruits constantly increased from the time of fruit-set to ripening (Table 4). In contrast, Lavee (1986) indicated that ABA content in olive fruit decreases during ripening.

The first harvest typically begins around 5 November, 15 November and 15 December and lasts until 15 December, 20 December and 10 January for 'AL-Salt', 'Madaba' and 'Jerash' locations, respectively. ABA, GA_3-like and kinetin-like hormone concentrations in November prior to the "on" year were highest in 'AL-Salt' and followed by 'Jerash' and 'Madaba' locations.

GA_3-like content was undetectable in 'Madaba' location while the level was about the same in both "on' and "off" year in 'Jerash' location. ABA and kinetin-like cytokinin levels in the "off" year were lower than in the "on" year in all three locations during the initiation period in November. The greatest bloom and fruit-set was found in 'AL-Salt', followed by 'Jerash' and 'Madaba' locations.

These data indicated that high concentrations of hormones, especially GA_3-like substances during the initiation period, promoted vegetative bud formation while lower concentrations favored flower bud formation. On the other hand, the lower levels of GA-like substances and slightly higher levels of ABA favored flower bud formation during the fall initiation period. Similar results were obtained in mango by Chen (1987).

Several studies evaluated exogenous applications of growth regulators to improve olive yield in the "off" year (Akillioglu, 1991; Lavee *et al*., 1983). However, no commercial recommendations have been adapted from these studies. GA-like substances and IAA concentrations were found to be higher in the "off" year while levels of kinetin-like substances were found to be essentially the same in both "on' and "off" years during bloom (May). Low levels of GA-like and high levels of ABA were associated with blooming and fruit setting.

Ferguson (2006) indicated that phytohormones have a triggering effect on the initiation of vegetative and flower buds on the new shoot growth of olives. Levels of endogenous phytohormones in July, November, January and March months were found to be critical for flower bud induction and development. If endogenous hormone levels are high during these months, vegetative bud formation is induced while low levels promote flower bud formation. The GA-like concentrations and GA: ABA ratio from November to January appears to have an effect on flower bud formation. High levels of leaf GA in July previous to the "off" years promoted vigorous shoot growth and reduced flower bud formation. If leaf ABA levels were found to be higher than GA levels, flower bud formation was increased during the initiation period. On the other hand, if ABA levels were lower than GA_3, vegetative buds formations were favored. High GA-like concentrations in apical buds in the "off" year, especially in March during the differentiation period, affected the number of annual shoots. High GA-like concentrations during this time increased annual shoot formation, whereas low concentrations decreased shoot numbers. These data indicated a general interrelationship between plant hormone concentrations and alternate bearing in olives. So, olive tree growers are advised to do fruit thinning during "on" year crop during June to July to reduce the production of GA_3, in order to reduce the occurrence of this phenomena and to distribute fruit bearing on two rather than one year which will be reflected on tree health and fruit quality.

ACKNOWLEDGMENT

I would like to thank the Agricultural Engineering teams, who worked in different locations in doing the experiment and collecting the data and a special thanks to Mr. Ahmad Nweran who leads the team.

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