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Response of productivity and competitive indices of pomegranate trees and sweet basil and rosemary to different intercropping systems

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ABSTRACT

Two field experiments were conducted at privet Orchard, Assuit Governorate, Egypt, during 2016/2017 and 2017/2018 seasons. This work aimed to evaluate growth, leaf chemical constituents and yield components of pomegranate as well as sweet basil and rosemary plants and some competitive indices between them at different row ratios (sole crop of each components, 1:2, 1:3 and 1:4 of pomegranate: sweet basil or rosemary, respectively). The experiment was arranged in a complete randomized block design with seven treatments in three replicates. Results indicated that growth parameters (tree height, shoot length, leaf dry weight), leaf chemical constituents (N, P and K percentages and total chlorophyll), fruits quality (total soluble solids, total acidity percentage and anthocyanin content) of pomegranate trees were significantly increased, in most cases, under intercropping with aromatic plants. In most cases, the highest values in plant height, number of branches/plant, total fresh weight/plant and volatile oil yield /plant of sweet basil and rosemary were recorded with 1:3 and 1:4 systems compared to sole crop of each one. Competition indices, i.e., land equivalent ratio (LER), area time equivalent ratio (ATER) and land utilization efficiency (LUE %) revealed that, applied intercropping system (1:4) were more efficient than sole cropping and other ones under study. Aggressivity (A) estimation indicated that pomegranate was dominant while sweet basil or rosemary was dominated. Generally, this mixture (1:4 system) seems promising in the development of sustainable crop yield advantages with a limited use of external inputs under Assuit Governorate conditions.

Keywords: Pomegranate, sweet basil, rosemary, intercropping system, yield, LER, ATER and A.

Introduction

Pomegranate (*Punica granatum* L.), belonging to the family *Punicaceae*, is one of the favorite table fruits and growing in the tropical and sub-tropical regions. This plant is native of Iran and is extensively cultivated in the Mediterranean region since ages (Sheikh and Manjula, 2009). The total areas of pomegranate in Egypt reached 34450 feds, out of them 11752 feds are fruitful producing about 106260 tons with an average of 9.42 tons/fed (Agricultural Statics, 2016). In the fact, pomegranate fruits have different industrial usage fields such as fruit juice, conserve, vinegar, citric acid and medicine, lead to its gaining popularity in the world markets (Aviram and Dornfeld, 2001). The fruit peel, tree stem, leaves and root bark are good source of secondary metabolites such as tannins, dyes and alkaloids (Mirdehghan and Rahemi, 2007).

Sweet basil (*Ocimum basilicum* L.) is a small perennial, culinary herb, tropically growing shrub of Asian origin (Dhar, 2002), widely used in systems of indigenous medicine (Paton, 1996). It belongs to the genus *Ocimum* (*Lamiaceae*), which contains up to 150 species of herb and shrubs in the tropical regions of Asia, Africa, and Central and South America (Simon *et al.*, 1990). Basil has also shown antioxidant and antimicrobial properties due to its phenolic and aromatic compounds (Gutierrez *et al*., 2008). The essential oil of sweet basil possesses antifungal, insect repellent and anti-toxic (Werner *et al*., 1995) and antiviral (Chiang *et al*., 2005) properties. *Rosmarinus officinalis* L. Family *Labiatae* is one of the herb spices that has antioxidative activity and is used as food additive. The compounds mainly responsible for these antioxidant properties are the carnosic acid and phenolic diterpenes carnosol (Brieskorn and Dömling, 1969). Furthermore, it is used for asthma, bronchitis whooping cough to stimulate poor circulation. It is employed for headache, palpitation, neuralgia, debility, rental

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fatigue, nervous exhaustion as well as stress-related disorders, dyspepsia, flatulence, hepatic disorders, jaundice and hypercholesterolemia (Dellacassa *et al.*, 1999).

The biological basis for intercropping involves complementarily of resources used by the two components (Barhom, 2001). Choice of the different crops in intercropping systems needs to be suitably maneuvered to harvest the synergism among them towards efficient utilization of resource base and to maximizing overall productivity (Mucheru-Muna *et al.*, 2010). The main concept of intercropping system is to get increased total yield and productivity per unit area and time. Various indices have been developed to indicate the competition and possible advantage in intercropping (Ghosh, 2004 and Alizadeh *et al.*, 2010).

The objective of this study was to define suitable some aromatic species for intercropping in commercials pomegranate production under different systems; determine growth, yield components, fruits quality of pomegranate trees as well as sweet basil and rosemary plants under Assuit Governorate conditions.

Materials and Methods

This study was conducted in two consecutive seasons (2016/2017 and 2017/2018) in pomegranate orchard, in Assuit Governorate, Egypt to investigate the influence of different intercropping systems on twelve years old trees of "Manfalouty" pomegranate cultivar. Trees were cultivated at 3.5 × 5 m apart under drip irrigation system with two lines per tree. Twenty eight trees similar in vigor and subjected to the same horticultural practices adapted in the region were used for this study.

The intercropping system treatments were as follows:

1- Sole cropping of each of pomegranate, sweet basil and rosemary. Such treatments were used as control for each one.
2 and 3- Intercropping system of 1: 2; since planting one row of pomegranate alternated with two rows of sweet basil or rosemary. Such pattern provides the proportional area of 69.60: 30.40 to each of pomegranate and sweet basil or rosemary, respectively.
4 and 5- Intercropping system of 1: 3; since planting one row of pomegranate alternated with two rows of sweet basil or rosemary. Such pattern provides the proportional area of 54.40: 45.60 to each of pomegranate and sweet basil or rosemary, respectively.
6 and 7- Intercropping system of 1: 4; since planting one row of pomegranate alternated with two rows of sweet basil or rosemary. Such pattern provides the proportional area of 39.20: 60.80 to each of pomegranate and sweet basil or rosemary, respectively.

These treatments were arranged in randomized complete blocks design with 3 replicates with four trees per replicate. The physical and chemical properties of the experimental soil are shown in Table 1, according to (Chapman and Pratt, 1978).

Table 1: Physical and chemical properties of experimental soil

Physical analysis											Soil texture
Clay (%)		Silt (%)		Sand (%)							Clay
51.36		33.20		15.44							
Chemical analysis											
pH	E C m.mohs / cm	Organic mater (%)	Soluble cations (meq. / L)			Soluble anions (meq. / L)			Available (ppm)		
			Mg^{++}	Ca^{++}	Na^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
8.12	1.33	1.36	2.3	1.4	4.1	4.5	1.7	4.1	9	28	71

Sweet basil and rosemary seedlings were transplanted on 15th April in both seasons between pomegranate trees rows. Seedlings were transplanted in single dripper lines with a distance of 80 cm between the dripper lines and 50 cm between the transplants at the same dripper line. The dripper discharge 4 L / h. Plot area was 19.2 m^2 (6 m in length and 3.2 m in width). All plants received

normal agricultural practices whenever they needed. The aromatic plants were harvested in two separated cut (100 and 200 days) from transplanting.

Data Recorded

1- Pomegranate trees:

Growth parameters as tree height (m), shoot length (cm) and leaf dry weight (g) (average of 25 leaves) as well as leaves chemical constituents as nitrogen, phosphorus and potassium percentages according to AOAC (1984) were determined. Total chlorophyll (SPAD unit) was determined in pomegranate fresh leaves by using SPAD- 502 meter (Markwell *et al.* 1995).

At the harvest time, fruit weight and number of splitting fruits percentage were estimated. Ten normal fruits were randomly taken from each tree to determine fruit quality characters. Fruit juice was extracted; and the total soluble solids (Brix˚) were determined using hand refractometer. Fruit total acidity content (expressed as citric acid/100ml Juice according to AOAC (1984) were calculated. Anthocyanin content (mg/100g) in fruits: a sample of fresh weighted fruits was determined cholorimertrically according to the method described by (Abou-Arab *et al.,* 2011). Fruit yield/tree (kg) was determined and then total fruit yield per faddan (kg) was calculated.

2- Aromatic plants:

Growth parameters as plant height (cm), number of branches/plant and total fresh weight/plant (g) as well as fresh herb yield/feddan were determined. Total chlorophyll (SPAD unit) was determined in sweet basil as well as rosemary leaves by using SPAD- 502 meter Markwell *et al.* (1995).

The volatile oil from air-dried leaves of sweet basil and rosemary plants was isolated by hydro distillation for 3 hr., in order to extract the volatile oils according to Guenther (1961) and the volatile oil yield per plant (ml) and per faddan (l) was calculated.

3- Competitive indices

a. Land equivalent ratio (LER)

This parameter was determined for pomegranate and sweet basil and rosemary yield recorded per feddan according to Mead and Willey (1980) equation as follows:

LER = LP + Lm,

$$\text{Lpomegrana te (Lp)} = \frac{\text{Ypa}}{\text{Ypp}} \qquad \text{Laromatic(La)} = \frac{\text{Yap}}{\text{Yaa}}$$

Where LP and La are the relative yield of pomegranate and aromatic plants (sweet basil and rosemary), respectively, as well as Ypp and Yaa are the yields per faddan of pomegranate and aromatic plants, respectively, as sole crops and Ypa and Yap are the yields of pomegranate and aromatic plants, respectively, as intercrop yields of each components.

b. Area time equivalent ratio (ATER)

It was calculated according to Hiebsch and McCollum (1987) equation as follows:

$$\text{ATER} = \frac{\text{Ypa}/\text{Ypp} \times \text{tp} + \text{Yap}/\text{Yaa} \times \text{ta}}{\text{T}}$$

Where: Ypa = intercropped yield of pomegranate, Ypp = sole yield of pomegranate, Yap = intercropped yield of aromatic plants, Yaa = sole yield of aromatic plants, tp = the duration of in pomegranate days (365 days), ta = the duration of aromatic plants in days (200) and T= the total duration of intercropping system in days.

c. Land utilization efficiency (LUE%)

By using LER and ATER values between caraway and onion, the land utilization efficiency (LUE %) was calculated according to Mason *et al.* (1986) equation as follows:

$$LUE = \frac{LER \times ATER}{2} \times 100$$

d. Aggrissivity (A)

Mc Gilchrist (1965) equation was used to calculated aggrissivity value as follows:

$$Apa = \frac{Ypa}{Ypp \times Zpa} - \frac{Yap}{Yaa \times Zap} \quad \text{and} \quad Aap = \frac{Yap}{Yaa \times Zap} - \frac{Ypa}{Ypp \times Zpa}$$

Where: Ypa = intercropped yield of pomegranate, Yap = yield of aromatic plants intercropped with pomegranate, Ypp = sole yield of pomegranate, Yaa = sole yield of aromatic plants, Zpa = sowing proportion of pomegranate and Zap = sowing proportion of aromatic plants.

Statistical Analysis

The statistical layout of this experiment was simple experiment in completely randomized block design. Least significance difference (LSD) was used to differentiate means at the at 5 % level of probability. The means were compared using computer program of Statistix version 9 (Analytical software, 2008).

Results and Discussion

Effect of intercropping systems on growth and productivity of pomegranate trees:

Growth and leaf chemical constituents:

Data presented in Tables (2 and 3) reveal that intercropping systems significantly increased pomegranate shoot length, dry weight of leaves samples, N, P and K percentages in leaves and total chlorophyll content as SPAD unit in the two seasons (2016/2017 and 2017/2018). In addition, the best treatment in this regard was alternating one row of pomegranate with four rows of sweet basil which followed by alternating one row of pomegranate with three and four rows of rosemary compared to the other ones under study. Ghosh and Pal (2010) indicated that phosphorus and potassium content in leaves of Mosambi significantly increased due to growing of different intercrops. Also, Suvera *et al.* (2015) found that growth characters and leaves chemicals contents (N, P and P) of *Pongamia pinnata* trees were increased when intercropped with *Ocimum basilicum* spp. plants.

Fruits quality and yield components:

Total soluble solids, total acidity percentage and anthocyanin content of pomegranate fruits were increased with intercropping system treatments by sweet basil and rosemary compared to sole planting. Such increase was significant by that of using 1 row of pomegranate: 4 or 3 rows of sweet basil and rosemary, respectively (Table 4). Also, Nandi and Ghosh (2016) showed that, from one year growing of medicinal plants clearly indicated that *Pudina* and *Bramhi* can be grown in the inter space of the orchard with no adverse effect on Mosambi sweet orange.

It is quite clear from the data in Table 5 that, *Ocimum basilicum* and *Rosmarinus officinalis* as intercropping treatments significantly decreased the fruit splitting percentage compared to sole pomegranate planting (control). The lowest fruit splitting percentage was observed with the treatments of 1row of pomegranate: 4 rows of aromatic plants (sweet basil and rosemary) compared to the other intercropping systems under study during both seasons. This may be attributed to the raising of humidity around the fruits with high plant density of the medicinal plants which reflected on decreasing pomegranate fruit splitting percentage. Moreover, all intercropping systems enhanced fruit weight, yield/plant and /feddan in most cases compared to sole planting system in both seasons.

Kanwar *et al.* (1993) reported that intercropped medicinal plants in citrus and mango orchards increased fruit quality as fruit weight, TSS, acidity and total sugar content compared solid planting patterns.

Table 2: Effect of intercropping system on vegetative growth parameters of pomegranate plant during the two seasons of 2016/2017 and 2017/2018

Intercropping systems as a rows ratio	Tree height (m)		Shoot length (cm)		Leaf dry weight (g)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Sole pomegranate	2.64	2.73	40.70	39.37	47.60	46.13
1 row P* : 2 rows S**	2.79	2.81	44.43	45.07	49.47	48.97
1 row P : 3 rows S	2.68	2.73	42.50	40.70	47.97	46.73
1 row P : 4 rows S	2.88	2.91	47.80	49.67	52.37	51.50
1 row P : 2 rows R***	2.66	2.70	40.20	40.97	48.97	47.10
1 row P : 3 rows R	2.80	2.87	46.67	48.17	51.77	50.87
1 row P : 4 rows R	2.75	2.91	46.10	45.77	51.53	50.37
L.S.D. at 5 %	**0.11**	**0.04**	**1.27**	**1.04**	**0.68**	**1.06**

* P: Pomegranate, **S: Sweet basil and ***R: Rosemary

Table 3: Effect of intercropping system on N, P and K percentages and total chlorophyll (SPAD unit) in leaves of pomegranate plant during the two seasons of 2016/2017 and 2017/2018

Intercropping systems as a rows ratio	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Total chlorophyll (SPAD)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Sole pomegranate	1.43	1.41	0.40	0.41	1.21	1.22	38.90	39.33
1 row P* : 2 rows S**	1.47	1.48	0.42	0.44	1.28	1.26	40.23	48.97
1 row P : 3 rows S	1.48	1.49	0.45	0.47	1.27	1.30	42.97	46.73
1 row P : 4 rows S	1.53	1.50	0.50	0.50	1.35	1.33	45.03	51.50
1 row P : 2 rows R***	1.43	1.43	0.42	0.43	1.28	1.26	39.77	47.10
1 row P : 3 rows R	1.51	1.51	0.46	0.47	1.32	1.33	44.37	50.87
1 row P : 4 rows R	1.49	1.50	0.47	0.47	1.31	1.31	42.27	50.37
L.S.D. at 5 %	**0.03**	**0.02**	**0.01**	**0.01**	**0.02**	**0.01**	**1.17**	**0.93**

* P: Pomegranate, **S: Sweet basil and ***R: Rosemary

Table 4: Effect of intercropping system on fruits quality parameters of pomegranate plant during the two seasons of 2016/2017 and 2017/2018

Intercropping systems as a rows ratio	Total soluble solids (Brix°)		Total acidity (%)		Anthocyanin (mg/100g F.W.)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Sole pomegranate	15.53	15.20	1.37	1.40	16.33	16.33
1 row P* : 2 rows S**	15.60	15.57	1.47	1.50	17.33	18.33
1 row P : 3 rows S	15.93	15.87	1.48	1.51	19.33	19.67
1 row P : 4 rows S	16.53	16.60	1.54	1.63	21.00	21.67
1 row P : 2 rows R***	15.60	15.40	1.37	1.43	17.33	17.00
1 row P : 3 rows R	16.37	16.20	1.53	1.53	20.67	20.67
1 row P : 4 rows R	16.13	15.93	1.47	1.50	18.67	19.33
L.S.D. at 5 %	**0.24**	**0.44**	**0.11**	**0.13**	**1.57**	**1.43**

* P: Pomegranate, **S: Sweet basil and ***R: Rosemary

Table 5: Effect of intercropping system on fruits splitting and yield components of pomegranate plant during the two seasons of 2016/2017 and 2017/2018

Intercropping systems as a rows ratio	Fruit splitting (%)		Fruit weight (g)		Yield/ tree (kg)		Yield/ feddan (ton)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Sole pomegranate	13.83	13.33	318.7	321.7	38.93	39.37	9.34	9.45
1 row P* : 2 rows S**	11.00	11.23	354.3	359.0	39.07	39.17	9.38	9.40
1 row P : 3 rows S	10.33	10.60	382.3	373.0	38.87	39.20	9.33	9.41
1 row P : 4 rows S	8.77	8.33	387.0	386.7	40.53	39.83	9.73	9.56
1 row P : 2 rows R***	12.17	12.00	346.3	349.3	38.73	38.60	9.30	9.26
1 row P : 3 rows R	10.53	10.87	373.7	369.7	38.83	38.77	9.32	9.30
1 row P : 4 rows R	8.80	8.93	382.7	382.7	39.90	39.93	9.58	9.58
L.S.D. at 5 %	**0.79**	**0.67**	**12.35**	**12.94**	**0.65**	**0.82**	**0.15**	**0.20**

* P: Pomegranate, **S: Sweet basil and ***R: Rosemary

Effect of intercropping systems on growth and productivity of aromatic plants:

Growth and yield components:

Data recorded in Table 6 show that, plant height, number of branches per plant and total fresh weight of sweet basil were increased with intercropping system treatments compared to sole crop. Such increase was significant by using that of one row of pomegranate: four rows of sweet basil (1:4 system) in both seasons. However, the above-mentioned parameters were increased with increasing the number of rows of sweet basil from 2 to 3 under cropping system with one row of pomegranate. Furthermore, plant height, number of branches per plant and total fresh weight of rosemary recorded the highest values when rosemary plants intercropped with pomegranate at (1:3 and 1:4 systems) compared to sole crop and 1:2 system in both seasons (Table 7). Singh *et al.* (1985) observed that medicinal and aromatic plants like *Mentha* sp., *Cymbopogon martini*, *Rauwolfia serpentina*, *Cymbopogon flexuosus*, *Piper longum* and *Vetiveria zizanoides* performed better as intercrops in agroforestry system with Eucalyptus, poplar and *Leucaena leucocephala* trees. These results are in line with those found by Sujatha *et al.* (2011) on *Ocimum basilicum* and *Artemisia pallens* intercropped with arecanut (*Areca catechu* L.).

Table 6: Effect of intercropping system on vegetative growth and yield parameters of sweet basil plant in the first and second cuts during the two seasons of 2016/2017 and 2017/2018

Intercropping systems as a rows ratio	Plant height (cm)		Number of branches/plant		Total fresh weight/ plant (kg)		Herb fresh yield/ feddan (ton)	
	First season							
	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Sole sweet basil	71.67	80.33	28.67	38.00	1.03	1.11	10.85	11.67
1 row P* : 2 rows S**	88.33	81.33	32.33	40.33	1.07	1.17	3.43	3.74
1 row P : 3 rows S	92.00	102.33	37.00	49.00	1.16	1.34	5.55	6.42
1 row P : 4 rows S	96.33	107.00	38.67	48.67	1.09	1.27	6.98	8.13
L.S.D. at 5 %	**3.24**	**2.77**	**0.94**	**2.42**	**0.03**	**0.04**	**0.19**	**0.29**
	Second season							
Sole sweet basil	74.00	81.00	32.00	40.00	1.06	1.12	11.13	11.78
1 row P* : 2 rows S**	89.33	83.00	36.67	42.00	1.07	1.21	3.43	3.85
1 row P : 3 rows S	94.67	100.00	39.00	53.00	1.18	1.44	5.67	6.91
1 row P : 4 rows S	98.67	107.00	37.00	48.00	1.14	1.30	7.30	8.30
L.S.D. at 5 %	**2.49**	**2.08**	**2.08**	**1.15**	**0.05**	**0.11**	**0.28**	**0.56**

* P: Pomegranate, **S: Sweet basil

Generally, fresh herb yield per feddan of aromatic plants (sweet basil and rosemary) was decreased when intercropped pomegranate trees compared to sole crop. However, the lowest fresh herb yield per feddan of aromatic plants produced from treatment of alternating one row of pomegranate with two rows of sweet basil or rosemary (1:2 system) in both seasons (Tables 6 and 7). Also, Abdelkader and Hamad (2015) have been found similar results on intercropped safflower and fenugreek.

Table 7: Effect of intercropping system on vegetative growth and yield parameters of rosemary plant in the first and second cuts during the two seasons of 2016/2017 and 2017/2018

Intercropping systems as a rows ratio	Plant height (cm)		Number of branches/plant		Total fresh weight/ plant (g)		Herb fresh yield/ feddan (ton)	
	First season							
	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Sole rosemary	33.33	29.33	5.33	7.67	22.40	39.00	235.20	409.50
1 row P* : 2 rows R**	34.33	31.33	6.67	8.33	29.63	39.37	94.59	125.66
1 row P : 3 rows R	35.67	33.00	6.33	11.00	31.37	42.93	150.19	205.56
1 row P : 4 rows R	35.33	33.67	6.00	10.67	29.27	43.43	186.84	277.28
L.S.D. at 5 %	**1.15**	**1.37**	**0.74**	**1.37**	**1.88**	**2.47**	**14.20**	**13.69**
	Second season							
Sole rosemary	31.00	29.00	6.33	8.00	24.03	39.23	252.35	441.95
1 row P* : 2 rows R**	32.33	29.67	6.33	11.00	30.27	44.40	96.61	141.73
1 row P : 3 rows R	35.33	34.67	7.67	14.00	35.33	55.30	169.18	264.78
1 row P : 4 rows R	34.00	32.33	7.00	13.33	33.60	52.47	214.50	334.95
L.S.D. at 5 %	**0.67**	**1.10**	**1.10**	**1.73**	**4.99**	**5.45**	**20.44**	**28.72**

* P: Pomegranate, ** R: Rosemary

Total chlorophyll and volatile oil production:

From data tabulated in Tables 8 and 9 it is clear that, total chlorophyll content in aromatic plants were increased with all intercropping systems compared to sole crops in the two seasons. Moreover, alternating one row of pomegranate with three rows of aromatic plants (1:3 system) recorded higher increase in volatile oil percentage and yield per plant compared with the other ones under study. Moreover, intercropping system treatments significantly increased volatile oil percentage and yield per plant, while, it decreased volatile oil yield per feddan of sweet basil and rosemary crops compared to sole crop pattern. The promotive effect of intercropping on active ingredients and chemical constituents which proved here was agreed with those stated by Karimzadeh *et al*. (2015) on dill essential oil production when intercropped with berseem plant and Gore *et al*. (2018) on Safed mulsi intercropped with pigeon pea. In addition, higher oil yield from Ocimum sanctum grown under agroforestry systems in W. Himalayas has also been reported by Thakur *et al.* (2009).

Effect of intercropping systems on competitive indices between pomegranate and aromatic plants:

The combined yield advantage in terms of land equivalent ratio (LER), area time equivalent ratio (ATER) and land utilization efficiency (LUE%) indices were the greatest in the cases of 1 pomegranate: 4 rosemary intercropping arrangement (1.74 or 1.84, 1.42 or 1.47 and 158.25 or 165.50) followed by 1 pomegranate: 4 sweet basil (1.71 or 1.69, 1.41 or 1.38 and 156.03 or 153.89) intercropping pattern arrangement in the first and second seasons, respectively (Table 10). This could be due to the reason that one to four pomegranate-rosemary as well as one to four pomegranate- sweet basil intercropping arrangement planted in the same inter and intra row spacing gave compatible more efficient total resource exploitation and greater overall production than sole crops and the remaining intercropping arraignments. However, similar results were reported by Bantie (2015) on potato intercropped with maize.

The data in Table 11 displays an effect of intercropping systems treatments on aggressivity (A) values of pomegranate (Apa) and aromatic plants (Aap) calculated for fruits and fresh herb yield per

feddan of pomegranate as well as sweet basil and rosemary respectively. In particular, pomegranate was the dominated one (Apa positive). Whereas, aromatic plants (sweet basil and rosemary) were the dominant species (Aap negative). Such aggressivity reached its maximum in the 1:4 pomegranate-sweet basil intercropping system which followed by 1:4 pomegranate-rosemary intercropping system in the first and second seasons.

In this respect, Dua *et al.* (2015) indicated that aggressivity values indicated that maize was a dominant species whereas, potato was dominated species when maize was supplied with N (50 or 100%), irrespective of N dose to potato. Also, Hamad (2017) reported that fennel plant was the dominant specie whereas fenugreek plant was the dominated one.

Table 8: Effect of intercropping system on total chlorophyll (SPAD) and volatile oil production of sweet basil plant in the first and second cuts during the two seasons of 2016/2017 and 2017/2018

Intercropping systems as a rows ratio	Total chlorophyll (SPAD)		Volatile oil (%)		Volatile oil yield /plant (ml)		Volatile oil yield /feddan (l)	
	First season							
	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Sole sweet basil	43.00	44.00	0.703	0.807	7.27	8.97	76.31	94.20
1 row P* : 2 rows S**	45.00	47.00	0.723	0.797	7.76	9.35	24.78	29.83
1 row P : 3 rows S	49.00	51.67	0.970	0.980	11.25	13.13	53.88	62.87
1 row P : 4 rows S	47.00	50.00	0.890	0.917	9.73	11.67	62.12	74.53
L.S.D. at 5 %	**2.31**	**2.07**	**0.028**	**0.031**	**0.35**	**0.51**	**2.78**	**4.90**
	Second season							
Sole sweet basil	41.33	43.00	0.687	0.763	7.28	8.57	76.42	89.98
1 row P* : 2 rows S**	46.00	49.67	0.717	0.817	7.70	9.85	24.58	31.46
1 row P : 3 rows S	48.33	51.33	0.983	0.960	11.63	13.86	55.71	66.34
1 row P : 4 rows S	45.67	50.67	0.923	0.907	10.57	11.78	67.45	75.21
L.S.D. at 5 %	**1.10**	**1.79**	**0.045**	**0.051**	**0.90**	**1.15**	**5.41**	**7.76**

* P: Pomegranate, **S: Sweet basil

Table 9: Effect of intercropping system on total chlorophyll (SPAD) and volatile oil production of rosemary plant in the first and second cuts during the two seasons of 2016/2017 and 2017/2018

Intercropping systems as a rows ratio	Total chlorophyll (SPAD)		Volatile oil (%)		Volatile oil yield /plant (ml)		Volatile oil yield /feddan (l)	
	First season							
	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Sole rosemary	37.00	35.67	0.243	0.253	0.055	0.100	0.573	1.037
1 row P* : 2 rows R**	38.00	37.00	0.253	0.247	0.075	0.097	0.240	0.313
1 row P : 3 rows R	41.33	42.33	0.283	0.277	0.089	0.117	0.426	0.570
1 row P : 4 rows R	39.00	42.00	0.277	0.267	0.081	0.117	0.517	0.737
L.S.D. at 5 %	**2.08**	**2.49**	**0.006**	**0.011**	**0.005**	**0.010**	**0.045**	**0.047**
	Second season							
Sole rosemary	37.67	37.33	0.423	0.257	0.059	0.101	0.614	1.058
1 row P* : 2 rows R**	40.00	39.33	0.253	0.273	0.077	0.121	0.245	0.387
1 row P : 3 rows R	43.67	41.67	0.283	0.300	0.100	0.166	0.479	0.794
1 row P : 4 rows R	41.67	41.67	0.277	0.287	0.093	0.150	0.593	0.960
L.S.D. at 5 %	**1.29**	**0.88**	**0.005**	**0.015**	**0.013**	**0.016**	**0.044**	**0.091**

* P: Pomegranate, ** R: Rosemary

Table 10: Effect of intercropping system on some competitive indices between medicinal plants and pomegranate during the two seasons of 2016/2017 and 2017/2018

Intercropping systems as a rows ratio	Land equivalent ratio		Area time equivalent ratio		Land utilization efficiency %	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Sole pomegranate	1.00	1.00	1.00	1.00	100.00	100.00
1 row P* : 2 rows S**	1.32	1.31	1.18	1.17	124.99	124.09
1 row P : 3 rows S	1.53	1.54	1.30	1.29	140.99	142.08
1 row P : 4 rows S	1.71	1.69	1.41	1.38	156.03	153.89
1 row P : 2 rows R***	1.34	1.33	1.18	1.18	125.94	125.83
1 row P : 3 rows R	1.55	1.64	1.30	1.34	142.45	149.06
1 row P : 4 rows R	1.74	1.84	1.42	1.47	158.25	165.50
L.S.D. at 5 %	**0.03**	**0.04**	**0.02**	**0.03**	**2.46**	**3.22**

* P: Pomegranate, **S: Sweet basil and ***R: Rosemary

Table 11: Effect of intercropping system on aggrissivity between aromatic plants and pomegranate during the two seasons of 2016/2017 and 2017/2018

Intercropping systems as a rows ratio	Aggrissivity pomegranate to aromatic plants		Aggrissivity aromatic plants to pomegranate	
	1st season	2nd season	1st season	2nd season
Sole pomegranate	0.00	0.00	0.00	0.00
1 row P* : 2 rows S**	+ 0.394	+ 0.385	- 0.394	- 0.385
1 row P : 3 rows S	+ 0.670	+ 0.627	- 0.670	- 0.627
1 row P : 4 rows S	+ 1.552	+ 1.461	- 1.552	- 1.461
1 row P : 2 rows R***	+ 0.305	+ 0.229	- 0.305	- 0.229
1 row P : 3 rows R	+ 0.623	+ 0.377	- 0.623	- 0.377
1 row P : 4 rows R	+ 1.430	+ 1.227	- 1.430	- 1.227
L.S.D. at 5 %	**0.058**	**0.116**	**0.058**	**0.116**

* P: Pomegranate, **S: Sweet basil and ***R: Rosemary

Conclusion

The present study indicates that intercropping of pomegranate with aromatic plants (sweet basil and rosemary) at different intercropping systems affects growth and productivity of the three species (pomegranate and aromatic plants) and also the competitive indices of the cropping system. The combined yield advantages in terms of land equivalent ratio (LER), area time equivalent ratio (ATER) and land utilization efficiency (LUE) were greatest in the cases of 1:4 pomegranate and aromatic plants cropping system as intercropping arrangement. In addition, these two intercropping systems were found to be the most profitable. These mixtures seem promising in the development of sustainable crop production with a limited use of external inputs. They can be used by the farmers in Assuit Governorate conditions as they are the most profitable systems with the greatest yield advantages.

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