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EFFECTS OF FENUGREEK AND DILL DIFFERENT INTERCROPPING PATTERNS AND HARVESTING TIMES ON ESSENTIAL OIL OF DILL

B. SHOKATI [1]*, K. GHASSEMI-GOLEZAN[1]

*E-mail: behzad.shokati66@gmail.com

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ABSTRACT. Intercropping is an important and sustainable cropping practice in agroecosystems. Intercropping is a planting technique that farmers and gardeners can use to promote beneficial plant interactions and increases in biodiversity, enhanced production and lower economic risk. In the search for sustainable agricultural methods for medicinal plants, fenugreek and dill plants were intercropped at different additive (1:20, 1:40 and 1:60) and replacement (1:1, 1:2 and 1:3) series, at the Research Farm of the Faculty of Agriculture, University of Tabriz, Iran. Field experiment was arranged as split plot based on randomized complete block design in three replicates. Dill umbels were harvested at flowering, pasty and complete ripening stages. Results showed that among harvesting times, pasty stage had maximum essential oil percentage, essential oil yield and harvest index of essential oil, whereas among intercropping patterns, 1:1 and 1:20 treatments had the maximum values. Fenugreek as a medicinal, forage and legume crop promote dill essential oil yield and harvest index and could be an effective plant in intercropping systems.

Key words: Additive series; Intercropping; Multiple culture; Replacement series.

INTRODUCTION

Dill (*Anethum graveolens* L.) is an annual herb used as carminative, and antispasmodic in medicine (Bailer *et al*., 2001, Sharma, 2004) and its essence has an inhibitory effect on stored potatoes sprouting (Zehtab-Salmasi *et al*., 2006). Catizone *et al.* (1986) reported that intercropping between annual dill (*Anethum graveolens* L.), and perennial clary sage (*Salvia sclarea* L.) improved the efficiency of cropping systems. Carrubba *et al*. (2008) indicated that the presence of dill exerted residue in the soil had a significant effect on fennel seed yields at following years.

Fenugreek (*Trigonella foenum-graecum*) is an annual crop from *Leguminoseae*. Seeds of this plant have been used extensively to prepare

[1] Department of Plant Eco-Physiology, Faculty of Agriculture, University of Tabriz, Iran

extracts and powders for medicinal uses (Basch *et al*., 2003). The major benefit of legume crops comes from biologically fixed N^2 deriving from the symbiosis involving leguminous plants and bacterial diazotrophs (Vance, 1998).

Plant mixtures can be formed by adding together the plant populations used in the pure stands (Agboola and Fayemi, 1971). This means that in such additive intercropping systems the total plant population of the mixtures is doubled when two crops are intercropped in this manner (Ebwongu *et al*., 2001). In other words, an inherent feature of additive intercropping is that the total plant population of the mixture is greater than that of the pure stands, which may contribute to its yield advantage. The alternative method of forming crop mixtures is the "replacement series" technique. In this method mixtures are formed by replacing a certain proportion of one species by another while keeping the total plant population pressure constant. The technique allows formation of a range of mixtures with different proportions of the two species (Willey and Osiru, 1972).

Some further interest in the potential role of medicinal and aromatic plants in intercropping systems has arisen from the widespread trend toward the cultivation of these plants. Nitrogen fixation by some plants may improve essential oil yield of medicinal plants in intercropping. Thus, this research was undertaken to evaluate the influence of dill and fenugreek intercropping on essence production of dill.

MATERIAL AND METHODS

The field experiment was conducted during 2011 at the Research Farm of the Faculty of Agriculture, University of Tabriz, Iran (38°5N, 46°E). The experiment was arranged as split plot on the basis of randomized complete block design with three replicates. In this study two medicinal plants of dill (*Anethum graveolens* L.) and fenugreek (*Trigonella foenum-graecum*) intercropped at different additive (1:20, 1:40 and 1:60) and replacement series (1:1, 1:2 and 1:3) (*Fig. 1*). The main and secondary crops were fenugreek and dill, respectively. As dill seeds are sensitive to seed bed, though soft and smooth seed bed prepared and covered by thin layer of sand silt. Each plot consisted of 10 rows and seeds were sown 20 cm apart and 1-2 cm deep. Optimum density for dill and fenugreek were 100 and 50 plant/m^2, respectively. Nitrogen fertilizer (15 kg/ha) was added to the plots at the early stages of growth as starter. Weeds were regularly controlled by hands.

Dill umbels were harvested at flowering, pasty and complete ripening stages. At each stage, 10 plants were harvested from each plot and the umbels were separated and dried. Then, dry umbels were watered with 500 ml distilled water and hydro-distillation was continued for 3 h, using a Clevenger-type apparatus (Europäische Arzneibuch, 1997). The essential oil was then separated and stored in dark glass bottles at 4°C. The data were analyzed by MSTAT-C and SPSS16.0 soft-wares and the figures were drawn by Excel 2010.

D	F	D	F	D	F	D	F	D	F
D	F	D	F	D	F	D	F	D	F
D	F	D	F	D	F	D	F	D	F
D	F	D	F	D	F	D	F	D	F
D	F	D	F	D	F	D	F	D	F
1:1 replacement series									

F	D	D	F	D	D	F	D	D	F
F	D	D	F	D	D	F	D	D	F
F	D	D	F	D	D	F	D	D	F
F	D	D	F	D	D	F	D	D	F
F	D	D	F	D	D	F	D	D	F
1:2 replacement series									

D	F	D	D	D	F	D	D	D	F
D	F	D	D	D	F	D	D	D	F
D	F	D	D	D	F	D	D	D	F
D	F	D	D	D	F	D	D	D	F
D	F	D	D	D	F	D	D	D	F
1:3 replacement series									

20%of sole dill density	F F F F F	20%of sole dill density	F F F F F	20%of sole dill density	F F F F F	20%of sole dill density	F F F F F	20%of sole dill density	F F F F F
1:20 additive series									

40%of sole dill density	F F F F F	40%of sole dill density	F F F F F	40%of sole dill density	F F F F F	40%of sole dill density	F F F F F	40%of sole dill density	F F F F F
1:40 additive series									

60%of sole dill density	F F F F F	60%of sole dill density	F F F F F	60%of sole dill density	F F F F F	60%of sole dill density	F F F F F	60%of sole dill density	F F F F F
1:60 additive series									

Figure 1 - Dill and fenugreek intercropping patterns; "D" means dill and "F" means fenugreek

RESULTS AND DISCUSSION

Analysis of variance of the data (*Table 1*) showed that the effect of different intercropping patterns (main factor), harvesting times (secondary factor), and their interaction were significant on essential oil percentage and yield and also on harvest index. Almost in all the treatments intercropped dill plants produced a significantly higher amount of essential oil when compared to mono-cultured plants (*Table 2*). It seems that nitrogen fixation by fenugreek helped dill plants to improve essence production. Similarly, Maffei and Mucciarelli (2003) relived that in peppermint/soybean strip intercropping, essential oil content increased up to 50% and quality of essential oil improved.

Although there were no significant differences among intercropping patterns at flowering, 1:60 additive series had the highest essential oil percentage (67%) followed by 1:2 and 1:40 treatments (0.531 and 0.462%, respectively). Maximum essential oil yield were obtained from 1:2 and 1:60 treatments, respectively, although differences among treatments were not significant. Maximum and minimum harvest indices of essential oil were recorded for 1:2 and 1:20 treatments (0.101 and 0.03 %, respectively). The highest essential oil percentage at pasty stage was attained from 1:1 replacement series treatments. Among replacement series, 1:1 treatment and among additive series 1:20 treatment had the maximum essential oil yield. At pasty stage, 1:1 replacement series had the highest harvest index of essential oil (2.528%) followed by 1:20 and 1:2 treatments. The lowest essential oil percentage and harvest index at complete ripening stage were obtained from sole dill, but 1:20 additive series had maximum essential oil yield (*Table 2*).

Table 1 - Analysis of variance of the data for dill essential oil yield and harvest index

Source	df	Characters		
		Essential oil percentage (%)	Essential oil yield (g\m^2)	Essential oil harvest index (%)
Replication	2	0.060	0.829	0.005
Intercropping patterns (I)	6	0.600**	3.357**	0.493**
E_I	12	0.066	0.439	0.046
Harvest time (T)	2	22.008**	84.055**	8.384**
I×T	12	0.315**	1.861**	0.412**
E_T	28	0.062	0.492	0.044
Total	62			
C.V%		23.530	21.820	26.960

** Significant at p≤0.01

Essential oil production at flowering stage was lower than that at pasty and maturity stages (*Table 2*). In contrast, Yousefzadeh *et al*. (2011) showed that maximum essential oil percentage for Dragonhead (*Dracocephalum moldavica*) cultivars was observed in full flowering. Putievsky *et al*. (1988) also noted that essential oil content of oregano (*Origanum vulgare*) was higher in full bloom stage than in the stage of early flowering. In other research Mirza *et al.* (2011) indicated that the highest percentage of essential oil (2.8%) was recorded in full flowering stage of *Mentha piperita*, while *Salvia officinalis* had the highest percentage of essential oil in early flowering stage (3%).

The highest essential oil percentage, yield and harvest index were recorded for pasty stage, followed by maturity stage (*Table 2*). Similarly, Nancy *et al*. (2007) reported that the highest oil yields of dill were obtained when most of the fruits on primary umbels were pigmented but had not become dry and fully mature. Telci *et al*. (2006) showed that 20 days after flowering of *Coriandrum sativum* maximum essential oil content achieved. Arif *et al*. (2010) in sea buckthorn berries study reported that essential oil content increased by fruit maturity.

Aidi Wannes *et al*. (2009) indicated that the highest fruit essential oil of *Myrtus communis* was obtained 60 days after flowering stage. Nancy *et al*. (2007) also reported that oil yield declined with fruit maturity over the sampling period, particularly after the completion of fruit ripening and “seed” shatter, which strongly supports the results of this research.

Table 2 - Mean essential oil yield of dill affected by harvesting times and intercropping patterns

Harvesting time	Treatment	Characters		
		Essential oil percentage %)	Essential oil yield (g\m^2)	Essential oil harvest index (%)
Flowering stage	1:1	0.284 h	0.111 f	0.039 k
	1:2	0.531 h	0.292 f	0.101 ijk
	1:3	0.343 h	0.173 f	0.081 jk
	1:20	0.331 h	0.135 f	0.030 k
	1:40	0.462 h	0.163 f	0.052 k
	1:60	0.670 h	0.277 f	0.071 jk
	Sole dill	0.313 h	0.180 f	0.070 jk
Pasty stage	1:1	2.755 a	6.207 a	2.528 a
	1:2	2.390 b	4.783 b	1.424 bc
	1:3	1.573 cd	2.559 cd	0.649 efg
	1:20	2.247 b	5.367 ab	1.55 b
	1:40	1.492 cde	3.002 c	0.797 de
	1:60	2.134 b	3.3 c	0.834 cd
	Sole dill	1.745 c	3.089 c	1.176 cd
Full ripening	1:1	1.2425 ef	1.326 def	0.462 efghij
	1:2	1.391 def	1.165 ef	0.409 fghijk
	1:3	1.573 cde	1.058 ef	0.491 efghi
	1:20	1.545 cd	2.329 cde	0.599 efgh
	1:40	0.578 g	0.578 f	0.187 hijk
	1:60	1.166 f	1.437 def	0.37 ghijk
	Sole dill	0.465 g	0.399 f	0.144 ijk

Different letters in each column indicate significant difference at $p \leq 0.05$.

CONCLUSIONS

It could be suggested that intercropping of dill with nitrogen fixing plants such as fenugreek can enhance essential oil production per unit area. In the trial environment, the technique showed a good potential to improve the efficiency of resource utilization, although further long-term experiments will be necessary in order to demonstrate the application of such a technique to other medicinal and aromatic plant mixtures.

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