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A STUDY OF INTERCROPPING OF MAIZE WITH SWEET BASIL AND BORAGE

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ABSTRACT. Intercropping is one of the environmental friendly ways to improve the use of resources and weed control. A field experiment was performed on maize intercropped with sweet basil and borage under weed free and infestation conditions. The experimental design was a factorial based on randomized complete block design with three replicates. Factors included weed infestation levels (weed free and weed infestated) and intercropping ratios (100:0, 75:25, 50:50, 25: 75, and 0:100, maize: sweet basil or borage). The intercroppping treatments decreased weeds biomass compared to the monocultures of borage and sweet basil. The weeds biomass and density in maize monoculture was lower than the monocultures of the other two plants. Under sole crop condition, the plants yield was higher than intercropping treatments. Weed interference decreased the yield of plants, while this decrease was less in intercropping treatments. Area-time equivalent ratio value showed that the ratios of 50:50 maize: sweet basil, maize: borage and 25:75 maize: borage provided the yield advantages of 11%, 11% and 36% under weed infestation, respectively. Also, area-time equivalent ratio values were higher in weed infestation compared to weed free treatments. The leaves essential oil of sweet basil under intercropping treatments, especially in weedy condition, was further than monocropping treatments. Intercropping of maize with sweet basil was more successful than intercropping with borage in reducing weeds biomass and density. In general, the intercropping of maize with sweet basil was more efficient compared to intercroppping with borage.

Key words: Area-time equivalent ratio; Essential oil; Plant height; Weeds population.

INTRODUCTION

Intercropping is defined as an environmental friendly method (Maffei and Mucciarelli, 2003; Agengnehu *et al.*, 2008). Nowadays,

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this method has become one of the popular methods in agricultural system due to the more efficient use of resources and and its role in reduction in weeds interference and other pests (Chen *et al.*, 2012; Lithourgidis *et al.*, 2011). It should be kept in mind that intercropping has a long history in food production in the world. Medicinal plants are considered as a source of health products, essential oils and other natural aroma chemicals in the national and international markets (Sujatha *et al.,* 2011). These plants have a special position in Iranian traditional medicine. In addition, many studies have emphasized the use of medicinal plants in intercropping systems, such as okra (*Abelmoschus esculentus* L.) (Muoneke and Mbah, 2007), chilli pepper (*Capsicum frutescens* Linn.) (Uddin and Odebiyi, 2011), saffron (*Crocus sativus* L.), three species of chamomile (*Matricaria chamomilla*, *Tanacetum parthenium* and *Anthemis nobilis*) (Naderi-Darbaghshahi *et al.,* 2012).

In addition to conserve the biodiversity, presence of medicinal plants in intercropping will also enhance yield quantity. For example, intercropping peppermint (*Mentha piperita*) plants with soybean produced a significantly higher amount of essential oil when compared to monoculture plants and the oil yield increased by 50% (Maffei and Mucciarelli, 2003). In many studies, one of the most common reasons for the adoption of intercropping is yield beneficial which is justified by the greater resource exploitation by intercrops than monoculture (Poggio, 2005). The more efficient exploitation of resources in intercropping happens because the component crops use the resources either at different times or obtain resources from different parts of soil or aerial environment (Echarte *et al.,* 2011). Regarding yield advantage, in a field study Esmaeili *et al.* (2011) reported that the total seed yield of barley (*Hordeum vulgare*) and annual medic (*Medicago scutellata*) was improved in some of the intercropping ratios when compared to the monoculture of either crop.

Another advantage of intercropping systems is weed suppression (Banik *et al.*, 2006). The reduction of weed growth by crop interference is a viable alternative to reduce the reliance on herbicide application in weed management (Poggio, 2005), as persistent application of herbicides has caused many severe problems such as evolving herbicide resistant weeds and environmental pollutions which has become a threat for human health and the sustainable development of agriculture (Chen *et al.,* 2012). In a study of wheat-bean intercropping weed suppression was successfully achieved in intercropping treatments. The weed control advantage in this study was reported to be due to an effective utilization of plant growth resources (Eskandari, 2011). In a wheat-chickpea intercropping study, it was also observed that intercrops suppressed weeds in addition to increase total productivity per unit area and land use efficiency improvement (Banik *et al.,* 2006). Fernandez-Aparicio *et al.* (2010) reported that *Orobanche crenata* infection was controlled in faba bean, pea, lentil, and chickling pea when intercropped with berseem clover. Sweet basil and borage are one of the most important medicinal plants that have a special place in Iranian traditional medicine. On the other hand, there is a little bit information on intercropping of these plants. Therefore, the objectives of this study were to: 1) determine weed suppression ability of intercropping; 2) determine yield advantages of intercropping systems; 3) study of essential oil percent and yield of sweet basil and borage intercropped with maize.

MATERIAL AND METHODS

The study was conducted in 2011 at a field located in the west of Shirvan, Northern Khorasan, Iran (37° 25´N, 57° 49´E, and altitude 1075 m.a.s.l). The mean annual rainfall was 244.2 mm, mean annual air temperature was 13˚C (*Table 1*). The soil characteristics are given in *Table 2*.

Table 1- Monthly and annual mean temperature, rainfall and wind speed recorded at experimental site during growing season

Months	Air temperature (˚C)		Rainfall (mm)		Wind speed ($m.s^{-1}$)	
	2011	2004-2011	2011	2004-2011	2011	2004-2011
June	22.7	21.4	22.6	14.7	12	16
July	24.4	25.4	13.7	7	11	14
August	25.3	24.8	0.7	6.6	11	11
September	20.2	21.6	9.9	10.8	12	15
October	15.3	16.2	6	4.8	11	14
Mean annual	-	12.9	-	244.2	-	17

Table 2 - Selected properties of the soil (0-30 cm) at experimental site

pH	EC (dS/m)	Organic matter (%)	P[1] (ppm)	K[2] (ppm)	N[3] (%)	Clay (%)	Silt (%)	Sand (%)
8.2	3.4	1.6	37.8	168	0.14	26	31	43

[1] Phosphorus; [2]Potassium; [3]Nitrogen

The experiment was conducted during June to October of 2011. The experimental treatments were arranged in a factorial design based on a randomized complete block with three replicates. The factors included different ratios of intercropping of maize with sweet basil and borage (100:0, 75:25, 50:50, 25:75 and 0:100 maize: borage (*Borago officinalis* L.) or sweet basil (*Ocimum basilicum*) and weed infestation levels (weed control and weed interference). Seed of crops were planted in plots with an area of 12 m^2 included six rows with 4 meters long and 50 cm apart, at the same day on June 1, 2011. The intra-row plant spacing for maize (*Zea mays* L. cv. S.C. 704), sweet basil and borage were 20, 5, and 33 cm, respectively. In weed control treatments, plots were kept free of weeds by implementing hand hoeing during the growing season. Weed was sampled by throwing a quadrat (0.5 m by 0.5 m) randomly at two sampling points in each plot at the time of maize harvesting. The weeds were identified, counted, then oven-dried at 75˚C for 72 h and expressed as g m^{-2}. Maize harvested as forage on September 1st. The samples were divided to stem, leaves and ear, then, the fresh weight was measured. The samples were oven dried at 75 ˚C for 72 h and weighed. Sweet basil was harvested with hand at two stages at the time of 10% blooming. First and second cutting was carried out on August 17th and September 30th, respectively. Borage flowers were harvested from July 25th to October 7th. Sum of all harvested flowers during growing season was placed as total yield of borage. The fresh weight of borage and sweet basil samples was measured then; samples were dried at 25 ˚C under the shade in order to maintain the essential oil content.

Sweet basil leaf oil extraction was done using the hydro-distillation method by placing 50 g of sweet basil leaves and 600 ml of water in a Clevenger type apparatus for 3h. Then, essential oil percent and oil yield was calculated. As the size of the borage samples was very small the essential oil extraction for borage was not possible.

In order to evaluate the yield advantage of intercropping systems compare to monoculture, area-time equivalent ratio (ATER) was calculated using the equation below:

$$ATER = [\{(Ymi \div Ym) \times tm\} + \{(Ypi \div Yp) \times tp\}] \div T$$

where *Ymi* is yield of maize in intercropping, *Ym* is yield of maize in monoculture, *Ypi* is yield of sweet basil and/or borage in intercropping, *Yp* is yield of sweet basil or borage in sole crop, *tm* is presence duration of maize, *tp* is presence duration of sweet basil or borage, and *T* is total duration of intercropping. The greater ATER value indicates efficient use of area and time (Ghosh *et al.,* 2006). SAS (version 9.2) and MSTATC programs were used to conduct an analysis of variance (ANOVA) and means comparison, respectively. Treatment mean differences were separated by a least significant difference (LSD) test at the 5% level of probability.

RESULTS AND DISCUSSION

Weed density and biomass

The dominant weeds in this experiment were *Chenopodium album* and *Solanum nigrum*. In addition to above-mentioned weeds, *Lactuca scariola, Amaranthus retroflexus, Convolvulus arvensis,* and *Heliotropium* sp. were also observed in this experiment. The density of *Chenopodium album* was greater than the other weeds.

Maximum weed biomass (316.5 g) and weed density (18.3 m^{-2}) was recorded in sweet basil monoculture. The weed biomass and density in maize monoculture were lower than the monoculture of two other plants (*Table 3*). Similarly, in a study of intercropping okra and cucumber it was noted that the monoculture of plants could not effectively control weeds (Ofosu-Anim and Limbani, 2007). The 75: 25, and 50: 50, maize: sweet basil had the lowest total weed biomass and density. In addition, compared to maize monoculture, these ratios reduced the *Chenopodium* *album* biomass by 55.02% and 57.17%, respectively, and reduced by 90.67%, 91.11% compared to sweet basil monoculture, respectively (*Table 3*). The lowest biomass of *Solanum nigrum* (0 and 6.5 g) observed in 50:50, maize: borage/sweet basil (*Table 3*). The highest density of total weeds and *Chenopodium album* was recorded in sweet basil monoculture and 50:50, ratio of maize: borage. While, the lowest density of *Chenopodium album* and *Solanum nigrum* was observed under 50:50, maize: sweet basil (*Table 3*). In fact, all intercropping proportions reduced the weed biomass compared to monoculture of borage or sweet basil (*Table 3*). These results are in agreement with the observations of Agengnehu *et al.* (2008) for wheat/faba bean intercropping. They reported that weed biomass in wheat/faba bean intercropping was lower than wheat sole crop. For example, weed biomass decreased by 28.71% in wheat/faba bean 100:62.5 compared to wheat sole crop. Banik *et al.* (2006) also noted that intercropping of wheat-chickpea at 20 cm spacing without weeding reduced weed biomass and weed population by 69.7% and 70%, respectively, compared to weedy monoculture of wheat at 20 cm spacing.

Table 3 - Effect of intercropping ratios on weed biomass (g) and density (m^{-2}) in weed infestation treatments

Intercropping ratios	Weed biomass (g)				Weed density (m^{-2})			
	C. album	*S. nigrum*	Other weed	Total	*C. album*	*S. nigrum*	Other weed	Total
Maize monoculture	61.7^{e}	13.8^{bc}	0.0^{c}	75.5^{def}	8.7^{bc}	3.0^{b}	0.0^{c}	11.7^{b}
Sweet basil monoculture	297.4^{a}	19.1^{a}	0.0^{c}	316.5^{a}	13.3^{ab}	5.0^{a}	0.0^{c}	18.3^{a}
Borage monoculture	234.4^{bc}	16.9^{ab}	0.0^{c}	251.2^{bc}	11.0^{bc}	4.3^{a}	0.0^{c}	15.3^{ab}
Maize 75:basil 25	27.8^{e}	10.5^{cd}	0.0^{c}	38.3^{ef}	3.3^{d}	2.0^{bcd}	0.0^{c}	5.3^{cd}
Maize 50:basil 50	26.4^{e}	6.5^{d}	0.0^{c}	32.9^{f}	3.0^{d}	1.0^{de}	0.0^{c}	4.0^{d}
Maize 25:basil 75	276.5^{ab}	9.6^{cd}	1.7^{b}	287.8^{ab}	11.0^{bc}	2.0^{bcd}	1. 3^{ab}	14.3^{ab}
Maize 75:borage 25	77.2d^{e}	13.7^{bc}	0.0^{c}	90.9^{de}	7.3^{cd}	2.7^{bc}	0.0^{c}	10.0^{bc}
Maize 50:borage 50	125.1^{d}	0.0^{e}	1.5^{b}	126.6^{d}	16.7^{a}	0.0^{e}	1.0^{b}	17.7^{a}
Maize 25:borage 75	188.7^{c}	13.9^{bc}	2.4^{a}	205.1^{c}	11.7^{abc}	1.7^{cd}	1.7^{a}	15.0^{ab}
Significance level	***	***	***	***	**	***	***	**
Coefficient of variation (%)	20.8	25.4	55.4	19.68	32.2	24.3	59.3	25.4
Least significant difference (5%)	52.7	5.1	0.6	53.92	5.3	1.0	0.5	5.5

, * indicated significant at P≤0.01, and P≤0.001, respectively. Means in a column with the same letter are not significantly different at 5%, based on LSD' test.

The other weeds were observed only under 25:75 maize: basil, 50:50, and 25:75 ratios of maize: borage (*Table 3*). The intercropping ratios of 75:25, 50:50, and 25:75, maize: sweet basil reduced the total biomass of weeds by 87.9%, 89.58%, and 9.08% compared to sweet basil monoculture, respectively. Furthermore, intercropping maize: borage ratios of 75:25, 50:50 and 25:75 decreased the total weeds biomass by 63.81%, 49.6%, and 18.38%, respectively, compared to borage monoculture. Less weed biomass and density under intercropping could be due to high inter-specific competition between intercrop crops which increased competitive ability of crops towards weeds (Banik *et al.,* 2006). Generally, intercropping of maize with sweet basil was more successful than intercropping with borage in reducing weed biomass.

Maize yield

Fresh and dry yield of sole plants were more than their intercrops in both weed infestation levels (*Table 4*). Similarly, Dhima *et al.* (2007) reported that the yield of cereal (wheat, barley, triticale, and oat) with vetch pure stand was more than the intercropping of cereal with vetch. Also, Ghosh *et al.* (2006) stated that the highest seed yield of soybean and pigeon pea was observed in monoculture and the seed yield of intercrop soybean and pigeon pea reduced by 16 and 26%, respectively.

Higher yield of monoculture compared to intercrop may be due to minimal disruption of the plants habitat (Banik *et al.,* 2006). Also, fresh and dry weight of leaves, stem, and ear in sole culture of maize were more than intercrops. Increasing the proportions of sweet basil and/or borage decreased the weight of leaves, stem, and fruit of maize (*Table 4*).

Under weed infestations, 75 (maize): 25 (sweet basil/borage) treatments didn't have any significant differences with monoculture of maize in components fresh yield (*Table 4*). When high efficient use in the resources occurred by the intercrop components, yield advantage of intercrops can be achieved (Hauggaard-Nielsen *et al.,* 2001). In this regard, Rezvani *et al.* (2011) reported that maize yield in 75:25 maize: soybean was higher than other treatments including sole culture of maize. Aynehband and Behrooz (2011) also reported that the highest maize forage yield was obtained in 75: 25, maize: amaranth. The highest percentage of fresh (18.69%) and dry weight (19.08%) of maize leaves were related to pure stand under weed infestation. Except 25:75 maize: borage ratio, weed interference increased the stem dry weight and decreased the ear dry weight in other treatments (*Table 4*). Increasing ratio of sweet basil and borage increased the maize ear dry weight. This increasing was evident in intercrop with borage (*Table 4*). Ofosu-Amin and Limbani (2007) reported that percentage of fruit set in cucumber increased in intercropping with okra. They expressed that percent fruit set was significantly lower (40%) in sole crop as compared to intercropping with okra. While, percentage fruit set in okra sole crop, was higher than intercropped treatments.

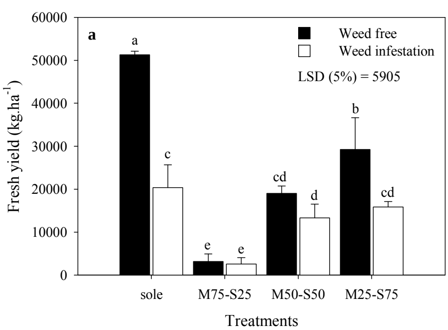
Table 4 - Interaction of intercropping ratios and weed levels on fresh and dry weight of parts and total of maize (t ha^{-1})

Weed treatments	Intercropping ratios		Fresh weight (t.ha^{-1})				Dry weight (t.ha^{-1})			
			leaves	stem	ear	total	leaves	stem	ear	total
Weed free	sole crop of maize		7.0	26.6^{a}	15.8^{a}	49.3^{a}	2.3^{a}	8.8	2.9^{a}	14.1^{a}
	maize: sweet basil	75: 25	5.5	18.2^{bc}	9.6^{c}	33.3^{c}	1.7^{b}	6.4	1.7^{bc}	9.8 ^{bc}
		50: 50	3.6	12.3^{d}	8.6^{c}	24.6^{de}	1.2^{d}	4.44	1.6^{bcd}	7.2^{de}
		25: 75	0.6	1.9^{e}	1.1^{e}	3.7^{f}	0.2^{f}	0.74	0.3^{f}	1.2^{f}
	maize: borage	75: 25	6.1	21.4^{b}	12.5^{b}	40.0^{b}	1.9^{b}	7.14	2.2^{b}	11.3^{b}
		50: 50	3.	10.2^{d}	5.5^{d}	18.7^{e}	0.9^{e}	3.64	0.9^{e}	5.5^{e}
		25: 75	0.7	2.4^{e}	1.1^{e}	4.2^{f}	0.2^{f}	0.74	0.3^{f}	1.3^{f}
Weed infestation	sole crop of maize		6.6	19.1^{bc}	9.6^{c}	35.2^{bc}	1.9^{b}	6.44	1.7^{bc}	9.9^{bc}
	maize: sweet basil	75: 25	5.1	16.5^{c}	7.8^{cd}	29.4^{cd}	1.4^{c}	6.04	1.3^{cde}	8.8^{cd}
		50: 50	3.0	11.8^{d}	5.6^{d}	20.5^{e}	0.9^{de}	3.74	1.1^{de}	5.8^{e}
		25: 75	0.7	1.5^{e}	1.7^{e}	3.9^{f}	0.2^{f}	0.74	0.2^{f}	1.1^{f}
	maize: borage	75: 25	5.5	16.8^{c}	9.2^{c}	31.5^{c}	1.4^{c}	5.84	1.4^{cde}	8.6^{cd}
		50: 50	3.4	11.3^{d}	6.9^{cd}	21.6^{e}	1.0^{de}	3.87	0.9^{e}	5.9^{e}
		25: 75	0.633	2.321e	1.7^{e}	4.7^{f}	0.2^{f}	0.7	0.3^{f}	1.2^{f}
Significance level (W×R)			N.S.	*	**	**	**	N.S.	*	*
Coefficient of variation (%)			10.2	16.6	23.7	16.1	12.2	19.3	29.2	17.9
Least significant difference (5%)			-	3.429	2.751	6.203	0.228	-	0.587	1.963

*, **, *** indicated significant at P≤0.05, P≤0.01, and P≤0.001, respectively; N.S. indicated non-significant difference. Means in a column with the same letter are not significantly different at 5%, based on LSD' test.

Sweet basil yield

The sweet basil dry yield in 25: 5, maize: sweet basil was higher than sweet basil pure culture under weed infestation (*Fig. 1b*). This increment indicated yield advantageous of intercropping compared to monoculture. In a study, Jena *et al.* (2010) cited that dry matter accumulation and yield in sesamum (*Sesamum indicum*) in 4:1 intercropped ratio with greengram (*Vigna radiata*) were higher than other treatments. In the other treatments, increasing the maize proportions decreased sweet basil yield (*Fig. 1a and b*). Maximum fresh and dry weights of sweet basil were observed in weed free treatments. Weed infestation decreased total dry weight of sweet basil by14.18% and 55.4% at first and second growing period, respectively (*Table 5*). Higher reduction in second growing period might be because of the lack of ability of sweet basil to re-growth quickly due to the presence of weeds. The fresh and dry yield (fresh weight (FW), stem dry weight (SDW), leaf dry weight (LDW), and total dry weight (TDW) of sweet basil were more in pure culture of sweet basil in first harvest and decreased by increasing maize proportions in intercrop. Whereas, at second harvest, maximum sweet basil dry yields (SDW, LDW, and TDW) were obtained in 25:75, maize: sweet basil (*Table 5*). Mahapatra (2011) reported that intercropping of sabai grass (*Eulaliopsis binata*) with blackgram (*Vigna mungo*) produced 19.7% to 22.5% higher dry leaf yield compared to monocropping system.



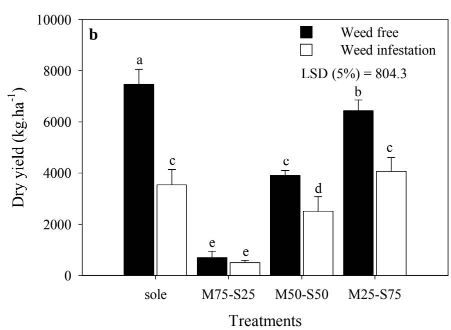


Figure 1- Interaction of intercropping ratios and weed levels on fresh yield (a) and dry yield (b) of sweet basil both total harvested. Sole: sole cropping of sweet basil; M75-S25: maize 75% + sweet basil 25%; M50-S50: maize 50% + sweet basil 50%; M25-S75: maize 25% + sweet basil 75%. Means with the same letter are not significantly at P 0.05 on LSD' test.

Table 5 - Effect of weed levels and intercropping ratios on fresh weight, stem dry weight, leaves dry weight and total dry weight of sweet basil at two growing period

Factors	First harvest yield (kg.ha^{-1})				Second harvest yield (kg.ha^{-1})			
	FW[1]	SDW[2]	LDW[3]	TDW[4]	FW	SDW	LDW	TDW
Weed (W)								
Weed free	8191[a]	655[a]	783[a]	1433[a]	17473[a]	1447[a]	1746[a]	3193[a]
Weed infestation	6309[b]	537[a]	753[a]	1229[a]	6697[b]	706[b]	717[b]	1424[b]
Significance level	**	N.S.	N.S.	N.S.	***	***	***	***
Least significant difference (5%)	1270	139	95	237	1884	203	123	274
Intercrop ratios (R)								
Sweet basil monoculture	14555[a]	1001[a]	1327[a]	2329[a]	21263[a]	1391[ab]	1780[a]	3171[a]
Maize 75: sweet basil 25	967[d]	101[d]	86[d]	204[d]	1874[d]	176[c]	218[c]	394[c]
Maize 50: sweet basil 50	5565[c]	500[c]	554[c]	990[c]	10588[c]	1125.8b	1094[b]	2220[b]
Maize 25: sweet basil 75	7912[b]	783[b]	1105[b]	1802[b]	14618[b]	1615[a]	1833[a]	3448[a]
Significance level	***	***	***	***	***	***	***	***
Least significant difference (5%)	1796	196	135	335	2664	287	174	387
Weed × Intercropping ratios	N.S.	N.S.	N.S.	N.S.	***	**	***	***
Coefficient of variation (%)	20.	26.7	14.2	20.4	17.8	21.6	11.4	13.6

[1]Fresh weight, [2]stem dry weight, [3]leaf dry weight, [4]total dry weight; **, *** indicated significant at P≤0.01, and P≤0.001, respectively; N.S. indicated non-significant difference. Means in a column with the same letter are not significantly different at 5%, based on LSD' test.

Borage yield

The highest fresh and dry yield of borage were observed in borage pure stand (*Table 6*). Iqbal *et al.* (2007) observed that intercropping of sorghum, sesame, and soybean with cotton significantly reduced cotton seed yield in a range of 8% to 23%. Weed interference decreased the fresh and dry yield of borage flower by 60.93% and 55.2% in monoculture, respectively. This reduction was averagely 33.82% and 41.21% for fresh and dry yield in borage intercropped with maize, respectively. Unlike the other plants, reduction in dry yield of borage flower was more evident than fresh yield in intercropping treatments (*Table 6*). The highest borage biomass was recorded in monoculture under the weed free condition. Similar to the yield, increasing in maize density decreased borage dry weight (*Table 6*).

Table 6 - Interaction of intercropping ratios and weed levels on fresh, dry yield (kg ha^{-1}) and total dry weight of plant (g. plant^{-1}) in borage

Weed levels (W)	Intercropping ratios (R)		Fresh yield (kg.ha^{-1})	Dry yield (kg.ha^{-1})	Plant dry weight (g.plant^{-1})
Weed free	Sole crop of borage		595.7^{a}	110.5^{a}	79.5^{a}
	maize: borage	75: 25	33.7^{d}	6.^{9c}	47.8^{f}
		50: 50	209.8^{c}	41.6^{b}	67.1^{cd}
		25: 75	417.2^{b}	90.7^{a}	69.3^{bc}
Weed infestation	Sole crop of borage		232.7^{c}	49.5^{b}	70.8^{b}
	maize: borage	75: 25	28.6^{d}	6.6^{c}	49.91^{f}
		50: 50	203.6^{c}	27.4^{bc}	63.9^{d}
		25: 75	228.6^{c}	48.3^{b}	58.7^{e}
Significance level (W×R)			***	**	**
Coefficient of variation (%)			19.8	29.2	3.2
Least significant difference (5%)			84.7	24.3	3.5

, * indicated significant at P≤0.01, and P≤0.001, respectively. Means in a column with the same letter are not significantly different at 5%, based on LSD' test.

Yield advantage

In fact, yield advantage can be expected at the maturity time of the intercrops when components are different, hence competition becomes less (Ghosh *et al.,* 2006). When land occupation time by intercrop components is different, area-time equivalent ratio (ATER) provides better estimates than land equivalent ratio (LER) (Awal *et al.,* 2007). ATER of each plant and total ATER in weed infestation treatments were higher than weed free ones. This increase indicated advantages of intercropping compared to monoculture under weedy condition (*Table 7*). ATER values based on fresh yield were higher in intercropping of maize with borage compared to intercropping with sweet basil. Whereas, based on dry yield ATER values were further in maize intercropped with sweet basil system than maize intercropped with borage (*Table 7*). As the values of ATER in maize based on fresh and dry yield were similar, changes in ATER values of total were related to ATER of sweet basil and borage (*Table 7*).

Total ATER values based on fresh yield were affected (p≤0.01) by interaction of weed infestation level and intercropping ratios (*Table 7*) and it was higher in 50:50, maize: sweet basil/ borage, and 25: 75 maize: borage in weed infestation (*Fig. 2*). These values indicated that 50:50 ratio of maize: sweet basil or borage obtained 11% and 36% yield advantages in fresh yield of intercropping, compared to monoculture (*Fig. 2*). Aasim *et al.* (2008) reported the 5-13% yield advantages based on ATER values in intercropping of cotton with cowpea. In intercropping of soybean with sorghum, Egbe (2010) reported that ATER values were above 1 in all treatments. Based on dry yield, ATER was only affected (p≤0.01) by simple effects of intercropping ratios and weed levels (*Table 7*). The ATER values based on dry yield were above 1 in 50:50, and 25:75, maize: sweet basil (*Table 7*). In intercropping of maize with borage ATER was lower than 1 in all treatments. These values indicated that intercropping maize with sweet basil had a high efficiency in use of growth resources when compared to pure stand (Vishwanatha *et al.,* 2011).

Table 7 - Effect of intercropping ratios and weed levels on ATER particle of plants and ATER total

Factors	ATER maize		ATER sweet basil		ATER borage		ATER total	
	fresh	dry	fresh	dry	fresh	dry	fresh	dry
Weed (W)								
Weed free	0.3[b]	0.31[b]	0.3[a]	0.5[b]	0.4[b]	0.3	0.7[b]	0.8[b]
Weed infestation	0.4[a]	0.41[a]	0.5[b]	0.7[a]	0.7[a]	0.6	1[a]	1.03[a]
Significance level	**	*	**	*	**	N.S.	***	**
Least significant difference (5%)	0.1	0.09	0.09	0.15	0.2	-	0.09	0.12
Intercropping ratios (R)								
Monoculture	-	-	-	-	-	-	1[a]	1[ab]
Maize 75: sbasil 25	0.6[a]	0.62[a]	0.1[c]	0.12[c]	-	-	0.7[c]	0.7[c]
Maize 50: sbasil 50	0.4[b]	0.42[b]	0.5[b]	0.6[b]	-	-	0.9[ab]	1.04[ab]
Maize 25: sbasil 75	0.1[c]	0.07[c]	0.7[a]	1.02[a]	-	-	0.8[bc]	1.1[a]
Maize 75: borage 25	0.6[a]	0.61[a]	-	-	0.1[c]	0.09[c]	0.7[c]	0.71[c]
Maize 50: borage 50	0.4[b]	0.36[b]	-	-	0.6[b]	0.5[b]	1.1[a]	0.8[bc]
Maize 25: borage 75	0.1[c]	0.08[c]	-	-	0.9[a]	0.9[a]	0.94[a]	0.99[ab]
Significance level	**	***	***	***	***	***	**	**
Least significant difference (5%)	0.1	0.15	0.12	0.18	0.2	0.2	0.1	0.24
Weed × Intercropping ratios	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	**	N.S.
Coefficient of variation (%)	28	34.9	20.87	23.8	32.64	36.56	16.8	21.7

*, **, *** indicated significant at P≤0.05, P≤0.01, and P≤0.001, respectively; N.S. indicated non-significant difference. Means in a column with the same letter are not significantly different at 5%, based on LSD' test.

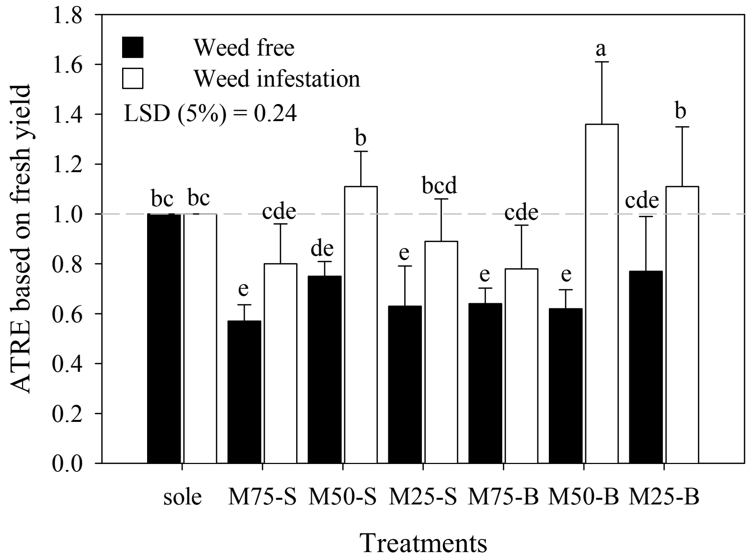


Figure 2 - Interaction effect of intercropping ratios and weed on ATER based on fresh yield of plants. Sole: sole cropping; M75-S: maize 75% + sweet basil 25%; M50-S: maize 50% + sweet basil 50%; M25-S: maize 25% + sweet basil 75%; M75-B: maize 75% + borage 25%; M50-B: maize 50% + borage 50%; M25-B: maize 25%+ borage 75%. Means with the same letter are not significantly at P 0.05 on LSD' test.

Essential oil of sweet basil leaves

The highest amount of sweet basil oil (0.76%) was achieved in 75:25 ratios under weed-free condition at the first harvest (*Fig. 3a*). The essential oil of intercropped sweet basil under weed infestation was more than weedy sole sweet basil in the first harvest (*Fig. 3a*). Our results are in agreement with the results of Maffei and Mucciarelli (2003). They noted that peppermint intercropped with soybean produced more essential oil and oil yield when compared to sole crop of peppermint. At the second harvest, the amount of sweet basil essential oil under weed-free conditions was higher than weed infested ones in all treatments except 25:75, maize: sweet basil (*Fig. 3c*). Similar to maize (25): sweet basil (75) at the second harvest, the amount of essential oil of sweet basil in the ratios of 50:50 and 25:75 maize: sweet basil under weed infestation was more than those of weed free treatments in the first harvest (*Fig. 3a and c*). Similarly, Alizadeh *et al.* (2010) stated that the amount of essential oil under weed interference conditions was higher than weed-free treatments. Also, Singh *et al.* (2010) noted that presence of cowpea as green manure increased the oil yield of menthol mint by 25.2% over the control without green manure. At the first harvest, the highest amount of sweet basil oil yield was evident in monoculture of sweet basil under weed-free and there was no significant difference between the ratios of 27:75, maize: sweet basil and the monoculture of sweet basil (*Fig. 3b*). This increase was related to high yielding in 25:75 ratios (*Fig. 1*). Similarly to the first period, the highest yield of essential oil was related to weed free treatments at second growth time (*Fig. 3d*). The most oil yield was obtained from sweet basil sole crop in weed control condition (*Fig. 3b,d*). Rajeswara Rao (2002) also noted that the intercropping of maize mint (*Mentha arvensis* L.f. *piperascens* Malinv. Ex Holmes) with rose-scented granium (*Pelargonium* sp.) decreased the essential oil of mint by 59.1% due to reduction in biomass yield compared to monoculture of maize mint. In addition, differences in total essential oil yield of rose-scented granium were not significant in sole and intercropping systems, because biomass yield of these cropping systems did not have significant variations. Mirhashemi *et al.* (2009) also reported that essential oil yield of ajowan (*Carum copticum*) intercropped with fenugreek (*Trigonella foenum-graecum*) was lower than sole crop of ajowan.

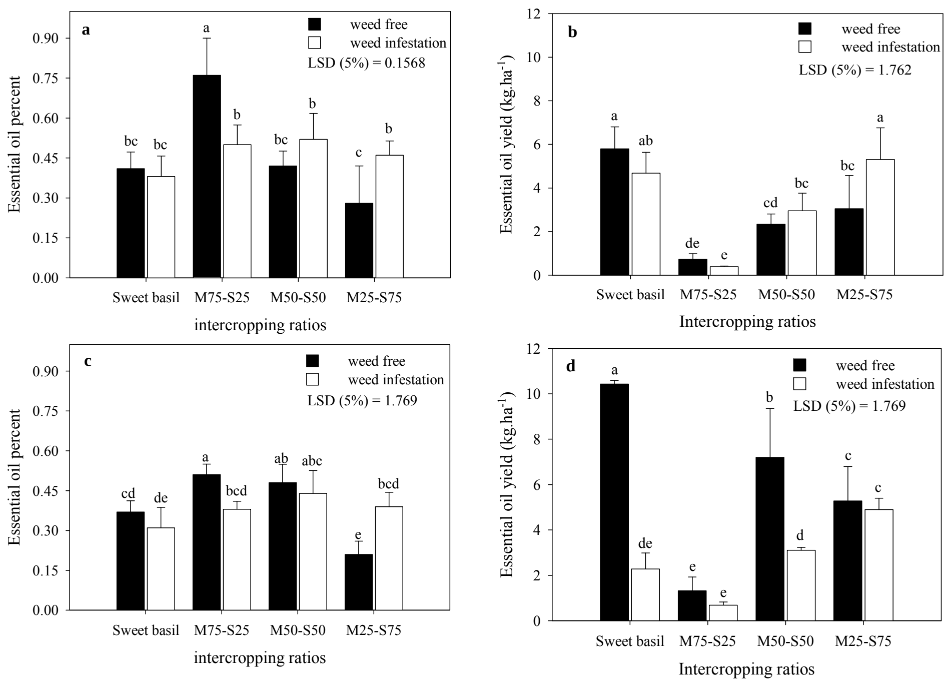


Figure 3 - Interaction of intercropping ratios and weed levels on essential oil percent (a, c), and essential oil yield (b, d) of sweet basil in first harvest (a, b) and second harvest (c, d). Sweet basil: sole cropping of sweet basil; M75-S25: maize 75%+ sweet basil 25%; M50-S50: maize 50%+ sweet basil 50%; M25-S75: maize 25%+ sweet basil 75%. Means with the same letter are not significantly at P 0.05 on LSD' test.

CONCLUSIONS

The results indicated that intercropping increased yield and essential oil percentage of sweet basil. The weed biomass and populations under intercropping systems were lower than sole crops. Thus, intercropping improved use efficiency of growth resources. Among intercropped treatments, intercropping of maize with sweet basil was more successful than intercrop with borage. In general, intercropping of 50:50, maize sweet basil could be proposed as an efficient system.

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