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ORIGINAL PAPER

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EFFECTS OF INTERCROPPING SYSTEM AND NITROGEN FERTILIZATION ON LAND EQUIVALENT RATIO, YIELD AND MINERAL CONTENT OF BROCCOLI

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ABSTRACT

To determine effects of intercropping broccoli with onion and their correspondence to different nitrogen concentrations on growth, yield and nutrient contents, field studies were conducted for two years. In intercropping plots, onion sets were planted between broccoli rows. Broccoli and onion plants were also grown as monocrops. Nitrogen (N) was applied at three different rates (160, 200 and 240 kg ha^{-1}) in both mono and intercrop plots of broccoli. The overall efficiency of intercropping was evaluated by employing land equivalent ratios (LERs). Cropping systems significantly did not affect chlorophyll reading value, yield and other parameters observed. However, nitrogen application rate had significant effect on these parameters. The highest values of these parameters were generally observed in 240 kg N ha^{-1} application. Macro and microelement content of broccoli leaves was affected neither by cropping systems nor by nitrogen fertilization except for N, Mn, Zn and NO_3. Intercropping increased plant height but decreased the plant diameter of onion. There wasn't significant decrease in plant weight of intercropped onion at 240 kg N ha^{-1} treatment when compared to monocropping. Broccoli intercropped with onion at 240 kg N ha^{-1} had the highest LER values, showing that intercropping practice could be more productive than monocropping especially in case of 240 kg N ha^{-1} application.

Key words: intercropping, nitrogen fertilization, broccoli, onion, yield, land equivalent ratios (LERs)

INTRODUCTION

Sustainable agriculture aims to simulate nature as the pattern for designing agricultural systems an important principle for sustainable agriculture is to create and maintain diversity, integrating plants and animals into a diverse landscape [Oad et al. 2007]. Agricultural systems must provide needs of people today and future generations; therefore, it seems that is essential achieving to sustainable agriculture. One of the key strategies in sustainable agriculture is restoration diversity to agricultural ecosystems, and its effective management [Shaker-Koohi et al. 2014]. Intercropping offers farmers the opportunity to engage nature's principle of diversity on their farms. Intercropping is a way to increase diversity in an agricultural ecosystem. Intercropping as an example of sustainable agricultural systems following objectives such as: ecolog-

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ical balance, more utilization of resources, increasing the quantity and quality and reduce yield damage to pests, diseases and weeds. Intercropping is an old and widespread practice in the low-input cropping systems of the tropics, and was common in developed countries before the fossilization of agriculture [Hauggaard-Nielsen and Jensen 2005]. In many earlier studies, it has been reported that the advantages of intercropping systems over mono cropping in different vegetable species [Yildirim and Guvenc 2005, Eskandari and Ghanbari 2009, Karlidag and Yildirim 2009a]. Yildirim and Turan [2013] reported that broccoli + leaf lettuce intercropping applications could improve total yield and productivity.

Currently, many intensive field vegetable production systems are not sustainable due to their severe environmental damage. Large amounts of nitrogen often remain in the soil after crop harvest. This nitrogen comprises residual soil nitrogen and nitrogen from crop residues. Both nitrogen sources affect groundwater quality through nitrate leaching and air quality through nitrous oxide emission [Guler 2005].

Recently, excessive amounts of fertilizers have been used on many soils for commercial vegetable production in Turkey. Nitrogen (N) being highly mobile in the soil, may result surface and ground water pollution through nitrate leaching and soil erosion [Schulte auf'm Erley et al. 2010]. N losses from the agricultural systems as N2, trace gases and nitrate leaching, potentially contributing to environmental pollution are greatly associated with vegetable production [Greenwood et al. 1990]. The main reason of environmental pollution is high N fertilization in commercial productions, which often exceeds the official recommendation limits [Schulte auf'm Erley et al. 2010]. Three main factors that affect plant nitrate accumulation are nutrition, environment and physiology [Anjana and Iqbal 2007]. Moreover, nitrate accumulation in vegetables is affected by the imbalance between nitrate absorption and reduction by plants [Wang et al. 2008]. Moreover, profitability is greatly influenced by N fertilization, which is one of the main costs of production.

Broccoli is greatly responsive to N fertilization. Balanced fertilization programs are necessary for normal plant growth, maximum yield per unit area, and good quality in *Brassica* species production [Atanasova 2008]. Among the major essential plant nutrients, N is required at high rates for Brassica species. The farmers generally use nitrogen fertilizers due to their fast intake by plants to harvest more yield. But, they need to use more N fertilizer to obtain more yield from the field due to short period availability of N fertilizers in soil. But, they need to use more N fertilizer to obtain more yields from the field due to short period availability of N fertilizers in soil. Although an apparently high demand of N for a better production has been reported, under non-optimal conditions broccoli may have lesser requirements of N; in these conditions surplus N may become a potential environmental problem [Mourao and Brito 2001]. Both excess and insufficient nitrogen applications may cause either yield reduction or some physiological disorders like hollow stem, and some pathological problems like head rot in the broccoli crop [Belec et al. 2001].

There is little information on broccoli-onion intercropping fertilized with different nitrogen doses. Therefore, the main objective of this work was to determine effects of intercropping broccoli with onion and their correspondence to different nitrogen doses on growth, yield and nutrient contents of broccoli.

MATERIAL AND METHODS

The present study was carried out in field conditions at University of Ataturk, in Turkey in 2013 and 2014. Erzurum is located at 39.933 N, 41.236 E; 1850 m altitude. Average yearly precipitation (1971–2013) is 404.9 mm, which is regarded semiarid climate. The mean temperatures, mean relative humidity and total precipitation values during growing period (May–July) were 15.33–16.30°C, 57.03–53.40%, and 65.20–59.20 mm, respectively in 2013 and 2014. The experimental area soil was aridisol according to the U.S. soil taxonomy. It was a loamy clay texture having 28.81% sand, 50.39% silt, 20.80% clay. Soil pH was 7.5, organic matter 1.77%, $CaCO_3$ 0.66%, total N 0.0091%, exchangeable Ca 14.13 $cmol_c\ kg^{-1}$, Mg 3.85 $cmol_c\ kg^{-1}$, K 2.57 $cmol_c\ kg^{-1}$, Na 0.79 $cmol_c\ kg^{-1}$, plant-available P 16.56 mg kg^{-1}, available Fe 4.13 mg kg^{-1}, Mn 4.56 mg kg^{-1}, Zn 3.45 mg kg^{-1}, Cu7.86 mg kg^{-1}, B 0.48 mg kg^{-1}.

Two treatment effects were studied in this study: cropping system (monocropping and intercropping) and N doses (160, 200 and 240 kg ha^{-1} as urea). Half doses of nitrogen and 200 P_20_5 kg ha^{-1} as triple super phosphate were applied with planting. Sole cropping onions were grown only with 100 kg ha^{-1} as urea 80 kg P_2O_5 ha^{-1} as triple super phosphate application as considered the control. Half of nitrogen was applied 30 days after planting.

The experiments were conducted using a randomized complete block design with four replicates. There were seven treatments: broccoli sole 160, 200, 240 kg ha^{-1}, broccoli+onion 160, 200, 240 kg ha^{-1}, and onion alone. The broccoli (*Brassica oleracea* L. var. *italica* 'Jade F1') as a main crop while onion (*Allium cepa* L. 'Urgup') as intercrop. Broccoli and onion plants were grown in pure stands as well as. Each plot size was 2.0 × 2.5 m. Broccoli seeds were sown into plastic trays filled with peat. Firstly, broccoli seedlings were kept in a controlled greenhouse and then transplanted after 30 days into field. Broccoli seedlings were planted in 0.60 × 0.50 m in sole and intercropping systems. In intercropping treatments, one row of onion (within-row plant spacing 0.05 m) was planted in the middle of between broccoli rows simultaneously in separate plots. In pure stands, onion spacing was 0.15 × 0.05 m. Sets (small dry bulbs, approximately 1/2 in.) were used for onion. Irrigation and weed control were regularly done. There was no any pesticides or herbicides application.

Broccoli plants were harvested when they were marketable size in early August in 2013 and 2014. The inner rows were used for sampling and harvest. Plants were cut at ground level, and yield, head weight, plant weight, leaf number, leaf weight, stem diameter, head diameter, and leaf and head dry matter ratio were determined for broccoli. The plant materials were kept in an incubator at 68°C during two days to determine dry weights. Fresh onion plants were harvested to determine for yield, stem diameter and plant weight.

Chlorophyll Reading Values (SPAD). A chlorophyll meter was used to determine chlorophyll content in leaves of broccoli (The Minolta SPAD-502).

Nitrate analysis. Analysis of nitrate has been done according to Cataldo et al. [1975].

Extraction and quantification of Vitamin C. Vitamin C analysis was done using liquid chromatography (HPLC) analyses.

MINERAL ANALYSIS

Leaf tissue sub samples were taken during head formation (five youngest leaves), oven dried at 68°C for 48 h, ground and passed through 1 mm sieve size. The Kjeldahl method and a Vapodest 10 Rapid Kjeldahl Distillation Unit (Gerhardt, Konigswinter, Germany) were used to determine total N. Macro- (P, K, Ca Mg and Na) and micro-elements (Fe, Mn, Zn, Cu and B) were determined after wet digestion (HNO_3-H_2O_2 acid mixture (2 : 3 v/v) of dried and ground sub-samples in microwave digestion (Bergof Speedwave Microwave Digestion Equipment MWS-2), by using an Inductively Couple Plasma spectrophotometer (Perkin-Elmer, Optima 2100 DV, ICP/OES, Shelton, CT 06484-4794, USA).

Land equivalent ratio (LER). The LER values were calculated as follows:

$$LER = LA + LB = AI/AS + BI/BS,$$

where LA and LB are the individual LERs of two crops A and B, LA is obtained by dividing the yield of crop A in intercropping (AI) by the yield of the same crop in sole cropping (AS). LB is calculated in the same way.

Statistical analysis. Data were subjected to the analysis of variance (ANOVA) to compare the effects of treatments. When significant differences occurred, the differences of means were determined using Duncan ($P < 0.05$).

RESULTS AND DISCUSSION

Broccoli growth and yield. To our best knowledge this is the first study on effects of intercropping broccoli with onion and their correspondence to different nitrogen doses on growth, yield and nutrient contents of broccoli. The study showed that cropping systems had no significant effect on yield and other parameters observed (Tabs. 1 and 2). Different growth parameters, i.e. plant weight per plant, leaf number per plant, leaf weight per plant, stem diameter, head diameter, head height head weight, head dry matter ratio, and yield exhibited a significantly response to higher N application fertilizer compared to lower fertilizer application treatments in both sole cropping and intercropping of broccoli. The maximum results were recorded from

Table 1. Chlorophyll reading value, plant weight, leaf number, leaf weight and stem diameter of broccoli in sole cropping and in intercropping at different nitrogen fertilizer rates

Nitrogen rate ($kg\ ha^{-1}$)		Chlorophyll reading value (SPAD)		Plant weight ($g\ plant^{-1}$)		Leaf number per plant		Leaf weight per plant ($g\ plant^{-1}$)		Stem diameter (mm)	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Sole cropping	160	67.20c*	74.26c*	839.00bc*	862.17c*	17.98d*	24.42d*	441.08c*	588.25cd*	25.97b*	33.02b*
	200	70.39b	77.98ab	861.92b	980.75b	21.83bc	25.59c	469.14b	620.00b	25.96b	34.22ab
	240	73.23a	79.15a	1026.91a	1152.00a	25.08a	27.17a	543.17a	770.00a	26.87a	34.67a
Inter-cropping	160	69.83b	75.39bc	807.58c	872.25c	18.25d	23.84d	421.42d	581.58d	24.33d	33.00b
	200	72.14a	78.66a	836.92bc	969.42b	21.17c	26.25b	452.58bc	609.42bc	25.37c	34.47a
	240	73.17a	80.48a	1051.92a	1139.75a	23.75ab	26.58ab	538.33a	755.00a	26.55a	34.44a

* Number with the same letters are not statistically different according to Duncan's multiple range test ($P < 0.05$)

Table 2. Head diameter, head height, head weight, head dry matter and vitamin C of broccoli in sole cropping and in intercropping at different nitrogen fertilizer rates

Nitrogen rate ($kg\ ha^{-1}$)		Head diameter (cm)		Head height (cm)		Head weight (g)		Head dry matter ratio (%)		Vitamin C ($mg\ 100\ g^{-1}$)		Yield ($g\ m^{-2}$)	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Sole cropping	160	12.17ns	9.44b**	10.92c*	9.57c*	244.92c*	250.00c*	11.67d*	10.48c*	185.00a*	206.00a*	783.73c*	800.00c*
	200	12.29	10.10a	11.06c	10.73ab	270.25b	268.25b	12.18bc	11.40ab	176.25b	200.50a	864.80 b	858.40b
	240	12.92	10.60a	12.38a	11.13a	340.00a	343.25a	12.54a	11.19b	160.25c	180.00b	1088.00a	1098.40a
Inter-cropping	160	11.75	9.34b	10.92c	9.25c	245.25c	244.75c	11.99c	10.41c	173.50b	209.50a	784.80 c	783.20c
	200	12.50	10.08a	11.71b	10.36b	271.75b	261.00bc	12.34ab	11.29ab	175.00b	197.25a	869.60b	835.20bc
	240	12.58	10.11a	12.18a	10.87ab	344.33a	348.25a	12.23bc	11.78a	172.25b	177.50b	1101.87 a	1114.40 a

ns Non-significant. * Number with the same letters are not statistically different according to Duncan's multiple range test ($P < 0.05$)

240 kg N ha^{-1}. But cropping systems did not significantly affect the plant growth parameters. Similarly, Santos et al. [2002] reported that intercropping with pea did not significantly affect yield of broccoli when compared to mono broccoli growing. Furthermore, when broccoli and cauliflower as a main crop were grown with different vegetable crops, their growth and yield were not adversely affected [Yildirim and Guvenc 2005, Unlu et al. 2008]. Moreover, it was found that intercropping with lettuce had no adverse effect on growth and yield of broccoli [Yildirim and Turan 2013].

Short season crops grown with long season ones for complementary depth and spread of root systems can prevent serious competition for resources, not interfering with the growth of long season ones. Short season crops may be harvested in time to make space for the long season ones. Management of component crops to increase their complementary effects, and to decrease competition depends on simple natural rules, and its practice is limited only by the imagination of farmers and agronomists [Midmore 1993].

However, nitrogen doses used generally improved plant growth and yield of broccoli. N fertilizer applications affected the weight of broccoli, and it increased with increase N doses applicant in both sole and intercropping system. Uher et al. [2017] indicated that yield depended on the increasing nitrogen dosage and obtained from the highest nitrogen dosage of highest broccoli yield. On the other hand, mono or intercropping system not affected the plant weight during two years. The highest plant weight was obtained from 240 kg N ha^{-1} application in both sole (1026.9 and 1152.0 g plant^{-1}) and intercropping (1051.9 and 1139.8 g plant^{-1}) system in 2013 and 2014, respectively.

The application of 240 kg ha^{-1} fertilizer during 2 years gave a highest increase in terms of leaf number and leaf weight per plant for sole (25.08 and 27.17 leaf number per plant, 543.2 and 770.0 g plant^{-1}) and intercropping (23.75 and 26.58 leaf number per plant, 538.3 and 755.0 g plant^{-1}) production system (Tab. 1). N doses have been found to be statistically significant effect on plant stem diameter but cropping production system is not. Maximum stem diameter was observed where 240 kg ha^{-1} dose of nitrogen application both sole (26.8 mm and 34.7 mm) and intercropping (26.6 mm and 34.4 mm) during 2 years, respectively (Tab. 1). Nitrogen fertilizer showed statistically significant improvement in head diameter, head height, head weight, head dry matter and yield of broccoli as compared to all other treatment. Maximum values were obtained from 240 kg ha^{-1} nitrogen application in both sole and intercropping in two-year experiment, those values were 12.92–10.60 cm, 12.58–10.11 cm for head diameter, 12.38–11.31 cm, 12.18–10.87 cm for head height, 340.0–343.3 g, 344.3–348.3 cm for head weight, 12.54–11.19%, 12.23–11.78% for head dry matter ratio and 1088.0–1098.4 g m^{-2}, 1101.8–1114.4 g m^{-2} yield of broccoli (Tab. 2), respectively.

Furthermore, nitrogen fertilizer application also resulted in significantly greater chlorophyll reading values and vitamin C when compared with control in both sole and intercropping cropping system (Tabs. 1 and 2). The highest chlorophyll and vitamin C content were recorded where 240 kg ha^{-1} dose N and chlorophyll and vitamin C during two-year experiment were 73.23–79.15 SPAD, 73.17–80.48 SPAD and 160.2–180.0 mg kg^{-1}, 172.2–177.5 mg 100 g^{-1}, respectively (Tabs. 1 and 2).

In both mono and intercropping system, nitrogen application increased weight per plant, leaf number per plant, leaf weight per plant, stem diameter, head diameter, head height, head weight, head dry matter ratio, yield, and chlorophyll content by 22.3–33.6%, 39.4–11.2%, 23.1–30.9%, 3.4–4.9%, 6.1–12.2%, 13.3–16.3%, 39.2–37.3%, 7.4–6.7%, 38.8–37.3% and 8.3–6.5% for sole cropping system, respectively and 30.2–30.6%, 30.1–21.5%, 27.7–29.9%, 9.1–4.3%, 7.0–8.2%, 11.5–17.5%, 40.4–42.3%, 2.0–13.1%, 40.2–42.2% and 4.7–6.7% compared to lower nitrogen dose, respectively (Tabs. 1 and 2). These results indicated that the use of N fertilizer in both sole and intercropping system lead to a significant increase in broccoli growth and yield compared to the control, but there were not any significant difference sole or intercropping system. Our findings were consistent with Babik and Elkner [2002] who reported that elevated N doses improved broccoli growth and yield. In fact it has been reported that inorganic nitrogen fertilization plays an essential role in increasing broccoli yield and quality [Yildirim et al. 2007]. Similarly, Uher et al. [2014] pointed out that nitrogen fertilization significantly affected growth, yield, β-carotene and vitamin C content of broccoli. They determined that 200 kg N ha^{-1} increased vitamin C content and the yield of broccoli. Both excess and insufficient nitrogen applications may cause either yield reduction or some physiological disorders like hollow stem, and some pathological problems like head rot in the broccoli crop [Belec et al. 2001].

PLANT NUTRIENT ELEMENTS

According to the data, it was evident that the application of N fertilizer in both mono and intercropping system promoted the contents of N, Zn and NO_3 content elements of broccoli plant, but not at all other nutrient content. Similarly, there were not statistically significant all nutrient content of broccoli under mono and inter cropping system (Tab. 3). Macro- and micro--element content of broccoli leaves was affected neither by cropping systems nor by nitrogen fertilization except for N, Mn, Zn and NO_3 (Tab. 3). As it results from Table 3, elevated soil nitrogen fertilization applications increased the content of N and NO_3 in leaves of both broccoli cultivars in two experiment years. Generally, the greatest values were obtained from 240 kg N ha^{-1} for both years. Mn and Zn values were inconsistent between years and treatments. Intercropping systems have been reported to increase total productivity since it utilizes nutrient elements in soil more efficiently than mono cropping [Eskandari 2011, Mobasser et al. 2014].

Table 3a. Macro-elements of broccoli in sole cropping and in intercropping at different nitrogen fertilizer rates

Nitrogen rate (kg ha^{-1})		N		P		K		Ca		Mg		Na	
		(%)		mg kg^{-1}									
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Sole cropping	160	2.48c*	2.59c*	2504^{ns}	2666^{ns}	12520^{ns}	13319^{ns}	8519^{ns}	8755^{ns}	4501^{ns}	4638^{ns}	784^{ns}	840^{ns}
	200	2.73b	2.81b	2587	2685	12664	13655	8572	9146	4543	4560	817	945
	240	2.94a	3.10a	2414	2832	12863	13884	8542	8916	4589	4837	813	926
Intercropping	160	2.59c	2.72c	2562	2745	13211	14489	8170	8555	4654	4869	747	838
	200	2.90b	2.92b	2672	2846	13498	14364	8244	8888	4716	4740	733	844
	240	3.11a	3.21a	2616	2566	13451	14463	8122	8927	4713	4592	749	851

ns: non-significant. * Number with the same letters are not statistically different according to Duncan's multiple range test ($P < 0.05$)

Table 3b. Micro-elements and NO_3 content of broccoli in sole cropping and in intercropping at different nitrogen fertilizer rates

Nitrogen rate (kg ha^{-1})		Fe		Cu		Mn		Zn		B		NO_3	
		mg kg^{-1}											
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Sole cropping	160	251.25^{ns}	217.25^{ns}	44.61^{ns}	52.24 ^{ns}	69.14a*	68.60a*	37.02a*	41.65a*	15.38ns	13.92 ^{ns}	848c*	941c*
	200	233.50	207.50	38.48	47.56	66.06b	56.97c	36.34a	39.94a	16.33	13.41	987b	1049b
	240	232.75	187.75	41.69	50.29	68.53a	60.09b	32.45b	35.61b	16.22	13.97	1185a	1220a
Intercropping	160	258.50	223.25	50.16	52.61	74.84b	70.46b	39.27b	42.56b	16.24	15.22	777b	826b
	200	258.25	229.25	50.21	53.73	78.55a	72.55a	43.14a	45.55a	16.98	17.01	804b	847b
	240	248.25	247.25	48.23	52.70	68.62c	66.52c	40.73b	45.02a	16.14	17.17	899a	970a

^{ns} Non-significant. * Number with the same letters are not statistically different according to Duncan's multiple range test ($P < 0.05$)

Intercropping practices have complementary effect for plants used in regard to resources uses, which utilize solar radiation, water and nutrient elements as compared to pure cropping [Eskandari 2011]. The successful intercropping applications improve to partake the available resources over time and space, using the differences between crops used in intercropping in terms of canopy growth rate, canopy and root structure [Midmore 1993]. Complementary effects of intercrops can be expressed as complementary resource use and niche differentiation in space and time, thus reducing competition between crop species and improving greater acquisition of limiting resources [Li et al. 2014]. Nutrient uptake of plants with different root architects in intercropping systems is higher than sole cropping as their root characteristics explores a larger soil mass. The capability of an intercropping system use for plant nutrient elements is affected from the extent of root growth of intercrops. Complementary usage of resources can be more effective when used crops with different root characteristics [Midmore 1993]. Competition for nutrient elements can be reduced in intercropping systems by choosing crops with different rooting characteristics, nutrient requirements, and timing of peak demand for nutrients. Nutrient competition is reflected by lower nutrient content in plant parts [Morris and Garrity 1993]. Many earlier studies pointed out that the plant nutrient contents of plants in intercropping practices were similar to the ones in monocropping, indicating the efficient use of available resources by intercrops [Santos et al.

2002, Yildirim and Guvenc 2005, Guvenc and Yildirim 2006, Yildirim and Turan 2013].

Onion growth and yield. Onion was used as the intercrop in this study. Intercropping broccoli with onion and their correspondence to different nitrogen concentrations significantly affected morphological characteristics of onion (Tab. 4). Different growth and yield parameters, i.e. plant height, stem diameter, plant weight per plant, and total yield of onion, exhibited a significantly higher response to N fertilizer application compared to low doses-fertilizer application treatments in intercropping systems. The maximum results were recorded from 240 kg N ha^{-1} in intercropping system. Moreover, intercropping elevated plant height of onion as compared to mono onion cropping, and decreased the stem diameter and plant weight.

Intercropping efficiency. The land equivalent ratio (LER) values as land use efficiency were always more than 1 in intercropping systems. The highest LER values were obtained from broccoli+onion combination when 240 kg N ha^{-1} was applied (Tab. 5). The result of the study indicated that broccoli intercropping with onion had LER values greater than 1 (Tab. 5), indicating the efficiency of land and resources use of intercropping over the monocropping. Intercropping of different vegetable crops has been shown the efficiency of intercropping over monocropping [Guvenc and Yildirim 2006, Karlidag and Yildirim

Table 4. Plant height, stem diameter, plant weight and total yield of onion in sole cropping and in intercropping at different nitrogen fertilizer rates

Year	Nitrogen rate (kg ha^{-1})		Plant height (cm)	Stem diameter (mm)	Plant weight per plant (g)	Total yield (g m^{-2})
2013	Sole crop onion		41.73c*	11.36a*	33.13a*	4306.58a*
	Onion intercrop	160	43.91b	10.16c	30.59b	764.63b
		200	43.88b	10.39bc	31.52b	788.06b
		240	45.18a	10.85ab	32.74a	818.38b
2014	Sole crop onion		40.35c*	16.32a**	43.52a*	1793.71a*
	Onion intercrop	160	43.03b	14.90b	40.13c	298.06c
		200	44.93a	14.99b	41.73b	315.69c
		240	44.33ab	14.06b	43.69a	392.21b

^{ns} Non-significant. * Number with the same letters are not statistically different according to Duncan's multiple range test ($P < 0.05$)

Table 5. Land equivalent ratio (LER) using the sole crop yield of broccoli from the corresponding N levels as control

Year	Nitrogen rate (kg ha^{-1})	Relative yield		LER
		broccoli	onion	
2013	160	1.00	0.17	1.17
	200	1.00	018	1.18
	240	1.01	0.19	1.20
2014	160	0.97	0.16	1.13
	200	0.97	0.17	1.14
	240	1.01	0.22	1.23

2007]. Intercropping systems can use present sources and be more effective especially if inputs such as water and nutrients are given to the plants in suitable quantity and time [Abusuwar and Al-Solimani 2013]. The differences of harvest time, root and above ground properties or intercrops resource usage can decrease competition among intercrops due to complementary effect of them [Midmore 1993].

Many studies pointed out that intercropping practices could increase total productivity and profitability in crops per unit area under field and greenhouse conditions [Karlidag and Yildirim 2007, Yildirim and Turan 2013]. This could be explained by the efficient use of available resources per unit area for different crops. Intercropping could be not only use limited areas for crop production more efficiently but also increase income. Higher returns under intercropping systems explained the suitability of intercropping systems to be adopted on a commercial scale [Yildirim and Guvenc 2005, Karlidag and Yildirim 2007, Karlidag and Yildirim 2009b, Mahant et al. 2012]. Rehman et al. [2010] determined that the maximum net farm and cost benefit ratio was obtained from maize intercropped with cowpea compared to the sole crops. These results indicated that the use of N fertilizer in both mono and intercropping system lead to a significant increase in land equivalent ratios (LERs) compared to the low doses N application (Tab. 5). The yield and plant growth enhancement effects of inter cropping and monocropping in this study on broccoli could be explained with fertilizer use efficiency, synergistic effects of plant and increasing soil biodiversity and sustainability.

CONCLUSIONS

The present study indicated that intercropping broccoli with lettuce was more productive than sole broccoli growing due to the complementary effects of the companion crops, particularly at 240 kg N ha^{-1}. These findings also show that the broccoli+onion combination should be used a suitable nitrogen fertilizer dose to improve the companion crops complementary. Onion could be successfully intercropped with broccoli without a remarkable decrease in broccoli yield. It can be concluded from the study that broccoli + onion intercropping with 240 kg N ha^{-1} application should be advised to the farmers to optimize their broccoli production in place of growing monocropping broccoli.

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