The Journal of Animal & Plant Sciences, 23(3): 2013, Page: 919-922
ISSN: 1018-7081

GROWTH, YIELD AND MINERAL CONTENT OF BROCCOLI INTERCROPPED WITH LETTUCE

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ABSTRACT

This study was conducted to determine the effect of intercropping with lettuce on growth, chlorophyll content, mineral content and yield of broccoli under field conditions during 2009 and 2010. The broccoli (*Brassica oleracea* L. var. italica) as a main crop was intercropped with leaf lettuce (*Lactuca sativa* L. var. crispa) as intercrop. The study was carried at University of Atatürk in Turkey. The experimental design was a randomised complete block design with three replications. Lettuce seedlings were planted in the middle of broccoli rows, both crops were also grown in pure stands as control. Results of this study indicated that intercropping systems compared to sole did not affect some growth characteristics and yield of broccoli except for weight per plant. Phosphorus (P), sulphur (S), iron (Fe), and manganese (Mn) content of broccoli leaves did not vary significantly depending on cropping systems. However, intercropping caused decrease in nitrogen (N), potassium (K), magnesium (Mg), calcium (Ca) and zinc (Zn) concentration compared to sole broccoli cropping. The study showed that broccoli based intercrop treatments might provide the highest total yield as well as productivity and profitability.

Key words: intercropping, broccoli, lettuce, growth, yield, LER.

INTRODUCTION

Globally, population increase and industrialization have resulted in cultivable land being decreased gradually. Arable lands are under pressure to produce for human consumption, especially in developing countries in Asia and Africa where growers own small plots of land (Awal *et al*., 2006). Intercropping has been considered advantageous in terms of economy of space, saving on tillage, use efficiency of nutrient and moisture in unused space. Intercropping, through more effective use of water, nutrients and solar energy, can significantly enhance crop productivity compared to the growth of sole crops (Yildirim and Guvenc, 2005). The increasing concern on agricultural sustainability favours the maintenance of the intercropping systems, due to an positive effect on soil conservation and improvement of soil fertility, more stable yields of intercropping systems using natural resources more effectively, and its great potential for pest and disease reduction (Guvenc and Yildirim, 2006).

Cultivation of several plant species side by side removes negative traits of a monoculture and therefore is commonly used in biodynamic gardens. This kind of cultivation is pro ecological; it supports bio-diversity and is compliant with the rules of balanced agriculture. Intercropping of vegetables is no novelty, yet in recent years, along with popularity of organic farming, it is being discovered again (Blazewicz-Wozniak and Wach, 2011).

Advantages of intercropping with legumes have been demonstrated in numerous studies; cauliflower with lettuce (Yildirim and Guvenc, 2005), cabbage with bean (Guvenc and Yildirim, 2006), cucumber with lettuce (Yildirim and Guvenc, 2004), eggplant with lettuce (Guvenc and Yildirim, 2005). Many studies have indicated that intercropping with different vegetables was more productive and profitable than sole cropping, because of the complementary effects of intercrops (Guvenc and Yildirim, 2006).

Broccoli is a relatively long-term crop and long-term crops in first growth stage may slowly grow and first establish full canopy after several weeks, opening an opportunity for a short-cycle crop like lettuce to be grown between rows. It has been reported that short season plants as lettuce grown between long season plants for complementary depth and spread of root architecture prevent from competition for light, water and nutrients (Yildirim and Guvenc, 2005).

The scope of improving vegetable production through suitable intercrop combinations has not yet been exploited to its full potential. The objective of this study was to optimize broccoli production in mixture by lettuce intercrops and evaluate the sustainability of intercropping systems based on broccoli on the basis of yield and LER (Land Equivalent Ratio).

MATERIALS AND METHODS

Plant material and setup of field trials: This study was conducted under field conditions at University of Ataturk, Hamza Polat Vocational School, in Upper Coruh Valley (Ispir) in Turkey during 2009 and 2010. Ispir is located at 40◦29 N latitude 41◦01 longitude, 1200 m above sea level. During 2009 and 2010, the growing period environmental conditions such as the mean maximum and minimum temperatures, mean relative humidity, mean wind speed, mean daily sunshine, total evaporation and total precipitation values [29.2°C, 10.4°C, 54.6%, 2.72 m s^{-1}, 11.2 h, 63.4 mm and 473 mm in 2009 and 29.0°C, 12.5°C, 56.0%, 3.50 m s^{-1}, 10.1 h, 49 mm and 448 mm in 2010] were similar, respectively between April and October. The soil of experimental area has had a loamy sand texture having 65.30% sand; 21.55% silt; 13.15% clay. Some of the soil chemical characteristics were as follows: soil pH 7.05; organic matter 1.30%; available P_2O_5 21 kg ha^{-1}; exchangeable K 2.0 meq100 g^{-1} soil. Manure (30 t ha^{-1}) was applied to plots. Fertilizers 180 kg/ha N and 100 kg P_20_5 kg ha^{-1} as ammonium nitrate and triple super phosphate were broadcast uniformly prior to planting on the soil surface and incorporated.

The experiments were conducted using a randomized complete design. The broccoli (*Brassica oleracea* L. var. italica) as a main crop while leaf lettuce (*Lactuca sativa* L. var. crispa) as intercrop. Both crops were grown also in pure stands as control. Thus, in total, there are three treatments, pure broccoli, pure lettuce, intercrop lettuce in broccoli. Broccoli and lettuce seeds were sown into plastic trays filled with peat (pH: 5.5, EC:250 dS m^{-1}, N:300 mg l-1, P: 131 mg l^{-1}, K: 333.33 mg l^{-1}, organic matter: 2%). Seedlings were initially grown in a greenhouse and then transplanted after about 1-month in rows in late June during both years. Broccoli spacing was 50 cm × 45 cm in both sole cropping and intercropping. Lettuce seedlings were planted in the middle of broccoli rows (within-row plant spacing 30 cm) simultaneously in separate plots. In pure stands, lettuce spacing was 30 x 30 cm.

Sprinkler irrigation was used as needed to prevent water stress. Weeds were controlled manually. Weeding was performed by hand whenever required. No pesticides or herbicides were applied.

After plant growth period, harvesting took place in September during both years. The inner rows were used for sampling and harvest. Entire plants were harvested at ground level from each plot when the terminal buds were swollen but not opened, and were weighed. The plants were then cut 20 cm below the top of head, which was trimmed to obtain a marketable product. Head diameter was measured across the widest part of head. The presence or absence of hollow stem was determined after cutting the stem longitudinally. Hollow stem incidence was observed rarely and so the results are not shown in the study.

Measured plant growth and yield parameters: Yield, plant weight, stem diameter, head diameter, and leaf and head dry matter ratio were determined for broccoli. The plant materials were dried in an oven at 70 ◦C until a constant mass was reached. Yield, stem diameter and plant weight were determined for lettuce.

Chlorophyll Readings: The Minolta chlorophyll meter SPAD-502 was used to estimate nitrogen concentration in leaves. Nitrogen is closely related to chlorophyll in leaves, therefore SPAD readings are a good indicator of the N status in crops. SPAD chlorophyll meter readings were taken from recently fully expanded leaves for each replicate, and the same leaves were used for chemical analyses (Alcantar *et al.,* 2002).

Plant analysis: Chemical analyses were performed with dry matter plant sample. Samples were taken from recently expanded heads of each plot. In order to determine the mineral contents of heads, plants samples were oven-dried at 70°C for 48 h and then ground. The micro-Kjeldahl procedure was applied for determination of N, P, K, Ca, Mg, Fe, Mn, Zn and Cu were determined after wet digestion of dried and ground sub-samples using a HNO3-H2O2 acid mixture (2:3 v/v) in three steps (145ºC, 75%RF, 5 min; 180ºC, 90%RF, 10 min and 100ºC, 40%RF, 10 min) in a microwave oven (Bergof Speedwave Microwave Digestion Equipment MWS-2). After filtration, P concentrations were determined by ICP-OES (Perkin-Elmer, Optima 2100 DV, USA; Mertens, 2005).

Land equivalent ratio (LER): The productivity of the intercropping was evaluated by the land equivalent ratio (LER). LER has often been considered to be an index of intercropping advantage. The LER defined 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 (Vandermeer, 1989).

Statistical analysis: Data were subjected to the analysis of variance (ANOVA) to compare the effects of treatments. When significant differences occurred, the means were separated using least significant difference test (LSD, $P < 0.05$). There were no significant interactions by year; therefore, the data were pooled.

RESULTS AND DISCUSSION

Influence of intercropping with lettuce on growth, yield parameters and LER of broccoli: The 2-year field trials showed non significant differences for yield per plant, chlorophyll content, stem diameter, head diameter, head dry matter ratio, and leaf dry matter ratio of broccoli in intercropping compared to sole cropping. But, broccoli weight per plant was significantly affected by intercropping with lettuce (Table 1). Similar results were found for stem diameter and yield per plant of lettuce. Sole lettuce growing values were the same with broccoli intercropping treatment (Table 2). Similar findings were reported in broccoli: green pea intercropping, broccoli yield was not affected compared to sole cropping, but there was a decreased in yield when intercropped with cauliflower (Santos et al., 2002). In an other study, cauliflower, broccoli and lettuce were intercropped with green pea, leek garlic, onion, green beans and radish, which there were no adverse effect in growth of main crops (Unlu et al, 2008). Splitstoesser (1990) reported that short season vegetables (e.g. peas, lettuce, kohlrabi, green onion) planted between full season vegetables for complementary depth and spread of root systems preclude serious competition for light, water and nutrients, which might be attributed to early maturing crops not interfering with the growth of late maturing ones in intercropping systems. It was also pointed out that short duration vegetables can be harvested in time to make room for the later maturing ones. (Splitstoesser, 1990).

Table 1. Yield, plant weight, stem diameter, head diameter, chlorophyll content head and leaf dry matter ratio and LER of broccoli in response to intercropping with lettuce.

	Control (broccoli)	Broccoli +lettuce
Yield per plant (g)	801 NS	785
Plant weight per plant (g)	2324 a*	2185 b
Stem diameter (cm)	2.71 NS	2.58
Head diameter (cm)	13.86 NS	13.54
Chlorophyll content	74.16 NS	73.16
Head dry matter ratio (%)	11.80 NS	11.87
Leaf dry matter ratio (%)	15.48 NS	14.71
LER	1.00 b*	1.21 a

*Means in row followed by different letters are significantly different ($\alpha < 0.05$)
NS: No statistically significant

Table 2. Effect of intercropping with broccoli on yield and stem diameter of lettuce.

	Control	Broccoli + lettuce
Yield per plant (g)	285 NS	291
Stem diameter (cm)	2.62 NS	2.51

NS: No statistically significant

LER values in this study were greater than 1 in the intercropped systems for both years (Table1), which means that productivity yield and the efficiency of land and resources use of these system over the sole cropping systems (Fukai and Trenbath, 1993). LER values were affected by intercropping and these effects were consistent during two years. In some studies conducted on these subject support those of Guvenc and Yildirim (2006), Karlidag and Yildirim (2007), Karlidag and Yildirim (2009) who investigated the efficiency of intercropping over sole cropping in different vegetable combinations. This efficiency might be attributed to more efficient use of available resources per unit area particularly when fertilizer and water were provided in adequate quantities (Sharaiha and Hattar, 1993; Abusuwar and Al-Solimani, 2013). In this study, the differences of growth time of maturity, morphological characteristics or resources use of main and intercrops might have reduced or postponed competition between component crops because of complementary effect of intercrops.

Plant nutrient concentration of broccoli intercropping with lettuce: Intercropping with lettuce also significantly affected plant nutrient concentration of broccoli (Table 3). In this study, we found that intercropping with lettuce treatments decreased N, K, Mg, Ca and Zn concentration, but P, S, Fe, and Mn content of broccoli was not affected compared to sole broccoli cropping. Intercropping systems provided to plant higher nutrient uptake per area than sole cropping because the root growth of component species with different root properties explored a larger soil mass. Nutrient competition can be minimized in intercropping systems by selecting species with different rooting patterns, nutrient requirements, timing of peak demand for nutrients or by proper plant spacing. Nutrient competition is reflected by lower nutrient concentrations in plant parts. In some studies conducted on this subject,

Table 3. Macro and micro element concentration of lettuce growth intercropping with broccoli

	Broccoli	Broccoli + lettuce
	%	
N	2.77±0.64 a*	2.24±0.25b
K	1.38±0.09 a*	1.26±0.01b
P	0.56±0.11 NS	0.48±005 NS
S	0.17±0.01 NS	0.16±0.01 NS
Ca	2.35±0.13 a*	2.24±0.77b
Mg	0.20±0.05 a*	0.18±0.08b
	mg kg-1	
Fe	87±2.2 NS	89±2.2 NS
Mn	23±4.2 NS	23±3.7 NS
Zn	25±22.6 a*	22±2.10b
Cu	10±1.2 b*	14±1.1a

*Means in row followed by different letters are significantly different ($\alpha < 0.05$)
NS: No statistically significant

similar and different results were obtained. Santos et al. (2002) reported that concentrations of N, P, K and Ca in leaves of intercropped broccoli with cauliflower and bean were similar to the monocrop ones. Varghese (2000) in cabbage, Yildirim and Guvenc (2005) in cauliflower, Guvenc and Yildirim (2006) in cabbage found that the nutrient concentrations of leaves of crops grown in intercropping systems were similar to the sole cropping ones, but some of the nutrient concentration changed. It might be attributed that this phenomenon by the efficient use of available resources per unit area for different crops.

Conclusion: Intercropping can result in an increase in the productivity of vegetables per unit area, and improve net income. The results of the present study concluded that broccoli intercropped with lettuce would be a remunerative cropping system which produced similar yields and economic returns when compared to a mono-crop of broccoli.

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