Available online at www.sciencedirect.com
SCIENCE DIRECT®

Europ. J. Agronomy 22 (2005) 11–18

European Journal of Agronomy
www.elsevier.com/locate/eja

Intercropping based on cauliflower: more productive, profitable and highly sustainable

Ertan Yildirim[a,*], Ismail Guvenc[b]

[a] Ispir Hamza Polat Vocational School, Ataturk University, P.O. Box 25900, Ispir, Erzurum, Turkey
[b] Department of Horticulture, Faculty of Agriculture, Ataturk University, Erzurum, Turkey

Received 17 April 2003; received in revised form 16 October 2003; accepted 2 November 2003

Abstract

The objective of this study was to determine the effect of different intercropping systems on growth, some mineral contents and yield of cauliflower under field conditions in 2000–2002. In addition, land equivalent ratio (LER) as an index of intercropping advantage and economic net income were determined to assess the efficiency of different cropping systems. The cauliflower (*Brassica oleracea* L. var. botrytis) as a main crop was intercropped with cos lettuce (*Lactuca sativa* L. var. longifoila), leaf lettuce (*L. sativa* L. var. crispa), radish (*Raphanus sativus* L.), onion (*Allium cepa* L.) and snap bean (*Phaseolus vulgaris* L. var. nanus) as intercrop. Each intercrop was planted in the middle of between cauliflower rows simultaneously in separate plots. All crops were grown also in pure stands. Results of this study indicated that different intercropping systems compared to sole did not affect some growth characteristics and yield of cauliflower except for radish as an intercrop. Net income increased when used cos lettuce, bean, leaf lettuce or onion as intercrop. LER values were always more than 1 in intercropping systems. Nitrogen, phosphorus, potassium, calcium, magnesium and iron content of cauliflower did not vary significantly depending on cropping systems. The study showed that cauliflower based intercrop treatments might provide the highest total yield as well as profitability.

Keywords: Intercropping; Cauliflower; Yield; Land equivalent ratio (LER); Income

1. Introduction

It is becoming more important to raise crop productivity in order to meet the increasing food requirements of an increasing population all over the world. Moreover, crop production per unit area must be increased because of remaining fixed or diminishing suitable land for food production. Intercropping, through more effective use of water, nutrients and solar energy, can significantly enhance crop productivity compared to the growth of sole crops (Midmore, 1993).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 (Jarenyama et al., 2000), more stable yields of intercropping systems using natural resources more effectively (Horwith, 1985), and its great potential for pest and disease reduction (Theunnissen,

* Corresponding author. Tel.: +90-442-451-2985-137; fax: +90-442-451-2959.
E-mail address: ertanyil@atauni.edu.tr (E. Yildirim).

1161-0301/$ – see front matter
doi:10.1016/j.eja.2003.11.003

1997). It has been demonstrated the advantages of intercropping in vegetables which could lead to better land use efficiency as an important component of sustainable farming (Guvenc and Yildirim, 1999).

To maintain yield and quality in intercropping systems, complementarity in patterns of resource use must be taken into account. Cultivars suitable for intercropping should enhance the complementary effects between species (Baumann et al., 2001).

Advantages of intercropping with legumes have been demonstrated in numerous studies; tomato or okra with cowpea (Olasantan, 1991), cabbage with bean (Poniedzialek et al., 1989), watermelon with soybean (Sharaiha and Hattar, 1993), chilli with bean (Costa and Perera, 1998). These studies have indicated that intercropping was more productive than sole cropping because of the complementary effects of intercrops. Furthermore, many authors showed favourable aspects of intercropping with non-legume vegetables under field conditions (Brown et al., 1985; Baumann et al., 2001). But the information is very scanty on intercropping with cauliflower in vegetable production.

According to the latest available statistics, the vegetables in Turkey are grown in area 800.000 ha with a total 22 million tons having an average productivity of 27 t/ha approximately. In Northeast of Turkey, suitable areas for crop production are limited, and average productivitiy of vegetables is approximately 14–15 t/ha which is rather lower than average productivity of vegetable in Turkey (Anonymous, 2002). 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 cauliflower production in mixture by choosing suitable intercrops and evaluate the sustainability of intercropping systems based on cauliflower on the basis of yield, LER and economic net income.

2. Materials and methods

This study was conducted under field conditions at University of Ataturk, Hamza Polat Vocational School, in Upper Coruh Valley (Ispir) in Turkey in 2000–2002. Ispir is located at 40°29′N latitude 41°01′E longitude, 1200 m above sea level and had a total rainfall of 136 mm in 2000, 280 mm in 2001 and 306 mm in 2002, and had average air temperature of 19.1 °C in 2000, 19.3 °C in 2001 and 17.6 °C in 2002 (April–September). The soil of experimental area in 2000–2002 has had a loamy sand texture having 68.4%, 64.9%, 65.30% sand; 19.9%, 28.0%, 21.55% silt; 11.7%, 7.10%, 13.15% clay respectively. Some of the soil chemical characteristics were as follows: soil pH 6.7 and 6.7 and 7.05; organic matter 1.44, 1.92 and 1.30%; available P_2O_5 13, 35 and 21 kg/ha; exchangeable K 2.3 and 3.5 and 2.0 meq/100 g soil in 2000–2002, respectively. Manure (30 t/ha) was applied to plots. 180 kg/ha N and 100 kg P_20_5 kg/ha as ammonium nitrate and triple super phosphate were broadcast uniformly prior to planting on the soil surface and incorporated.

The cauliflower (*Brassica oleracea* L. var. botrytis cv. Medal) as main crop was intercropped with cos lettuce (*Lactuca sativa* L. var. longifoila cv. Yedikule 44), leaf lettuce (*L. sativa* L. var. crispa cv. Iri Kivircik), radish (*Raphanus sativus* L. cv. Cherry Belle), onion (*Allium cepa* L. cv. Corum) and snap bean (*Phaseolus vulgaris* L. var. nanus cv. Gina). Intercropping treatments included cauliflower:bean, cauliflower:cos lettuce, cauliflower:leaf lettuce, cauliflower:radish and cauliflower:onion. All crops were grown also in pure stands.

The experimental design was a randomised complete block design with three replications. Each plot size was 4.5 m × 3.75 m. Cauliflower spacing was 75 cm × 75 cm in both sole cropping and intercropping. In intercropping treatments, one row of cos and leaf lettuce (within-row plant spacing 30 cm), radish (within-row plant spacing 5 cm), onion (within-row plant spacing 5 cm) or bean (within-row plant spacing 20 cm) were planted in the middle of between cauliflower rows. Cauliflower, cos lettuce and leaf lettuce were transplanted. Bean and radish were field seeded, and sets (small dry bulbs, approximately 1/2 in.) were used for onion. Main crop and intercrops were planted simultaneously on 15 May in 2000, on 18 May in 2001 and on May 15 in 2002. Sprinkler irrigation was used as needed to prevent water stress. Weeds were controlled manually.

Leaf number, leaf weight, stem height, curd diameter, curd height, curd weight and yield for cauliflower were determined. All observations were made from centre rows after border rows were discarded to avoid edge effects.

Some chemical analysis in cauliflower leaves was evaluated after harvest. The plant materials were dried in an oven at 70 °C until a constant mass was reached and then they were ground for chemical analysis. Total nitrogen was determined using the micro-Kjeldahl method (Kacar, 1972). After plant samples were wet-fired with nitric-perchloric acid, P was determined spectrophotometrically. K, Ca, Mg and Fe contents were determined using an atomic adsorption spectrophotometer (Kacar, 1972; Frank, 1975).

The productivity of the intercropping was evaluated by the land equivalent ratio (LER) and economic net income. 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).

Economic net income analysis was undertaken to assess economic feasibility of different intercrops. Cost of land, buildings and equipment were not included, as they were assumed to be the same for all systems. Material included all cash expense items of fertilizer, seeds, plant trays, crates, etc. Labor included family and unskilled hired labor. Machine operating costs was considered also (Brown et al., 1985). Crop prices which farmer had got were obtained from State Institute of Statistics Prime Ministry Republic of Turkey (Anonymous, 2002).

Data obtained in this study were subjected to analysis of variance (ANOVA) and the differences between means were tested according to Duncan's multiple range test.

3. Results and discussion

3.1. Growth

The effects of cropping systems on growth of cauliflower are presented in Table 1. While no significant differences were determined among-

Table 1
Mean leaf number, leaf weight, stem height, curd height, curd diameter and curd weight of cauliflower in response to various intercropping systems

Cropping system	Leaf number (per plant)	Leaf weight (g)	Stem height (cm)	Curd height (cm)	Curd diameter (cm)	Curd weight (g)
2000						
Cauliflower:bean	31.35 ab*	1760 NS	14.04 NS	10.51 NS	22.75 ab*	1783 a*
Cauliflower:cos lettuce	30.72 b	1633	12.84	10.57	22.87 ab	1782 a
Cauliflower:leaf lettuce	31.85 ab	1701	12.69	10.74	24.18 a	1796 a
Cauliflower:radish	30.33 b	1614	12.76	10.40	22.00 b	1668 b
Cauliflower:onion	31.30 ab	1683	13.43	10.90	23.88 ab	1793 a
Cauliflower sole	32.30 a	1733	12.71	11.01	24.63 a	1851 a
2001						
Cauliflower:bean	35.33 NS	1848 NS	12.80 NS	11.18 NS	23.84 ab*	1863 NS
Cauliflower:cos lettuce	33.87	1714	13.02	10.44	24.18 ab	1754
Cauliflower:leaf lettuce	33.90	1810	12.81	11.02	25.89 a	1867
Cauliflower:radish	32.53	1702	12.98	10.45	22.83 b	1741
Cauliflower:onion	33.20	1865	12.28	11.08	24.90 ab	1822
Cauliflower sole	35.30	1860	13.03	11.32	25.10 a	1874
2002						
Cauliflower:bean	33.94 a*	1840 a*	12.73 NS	11.51 NS	24.14 a*	1832 a*
Cauliflower:cos lettuce	32.07 ab	17662 ab	12.58	11.32	24.71 a	1784 ab
Cauliflower:leaf lettuce	32.85 a	1832 a	12.92	11.42	25.14 a	1879 a
Cauliflower:radish	30.44 b	1732 b	12.96	11.06	22.69 b	1709 b
Cauliflower:onion	32.23 ab	1803 ab	13.10	11.87	24.90 a	1837 a
Cauliflower sole	33.65 a	1835 a	13.22	11.61	25.14 a	1877 a

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

intercropping systems in terms of leaf number for cauliflower in 2001, in cauliflower:radish and cauliflower:cos lettuce intercropping in 2000, and in cauliflower:radish intercropping in 2002 the number of leaf of cauliflower was lower than that of sole. The leaf weight did not change depending on cropping systems in 2000 and 2001 but 2002. Stem height and curd height did not vary significantly in all years. When cauliflower was grown with radish in 2000–2002, curd diameter was decreased significantly compared to sole. There were no significant differences with the respect to curd weight between cropping systems in 2001, whereas radish as an intercrop reduced curd weight in 2000 and 2002. Similar findings that intercropping did not affect some growth characteristics of main crops were reported in tomato:lettuce (Erdogan and Karatas, 2000) and in cabbage:spinach (Varghese et al., 1990). Splitstoesser (1990) reported that the early-maturing crops would not interfere with the growth of the late-maturing ones. Our results agreed with also those of Varghese (2000), who found out radish as an intercrop affected adversely growth of cabbage due to radish.

3.2. Nutrient concentration

The concentration of N, P, K, Ca, Mg and Fe in cauliflower leaves in different cropping systems produced no significant response in all years (Table 2). Varghese (2000) indicated that intercropping with six different vegetables did not affect N, P and K content of cabbage compared to sole cabbage. Similarly, 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. This could be explained by the efficient use of available resources per unit area for different crops (Shultz et al., 1987; Sharaiha and Hattar, 1993). Greater nutrient uptake by intercropping has been shown by several authors (Woolley and Davis, 1991; Morris and Garrity, 1993; Varghese, 2000). Intercrop studies have shown that root competition for immobile macro-nutrients like P and K is unlikely (Midmore, 1993). Furthermore, Coolman and Hoyt (1993) and Zhou et al. (2000) noted that intercropping can improve N-use. The ability of an intercrop to make more efficient use than sole crops of soluble

Table 2
Nutrient concentration in relation to various cauliflower based intercropping systems

Cropping system	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)
2000						
Cauliflower	3.91 NS	0.44 NS	3.35 NS	0.46 NS	0.22 NS	91 NS
Cauliflower:bean	3.90	0.39	3.30	0.39	0.22	89
Cauliflower:cos lettuce	3.65	0.43	3.42	0.42	0.18	84
Cauliflower:leaf lettuce	3.78	0.44	3.33	0.45	0.20	88
Cauliflower:radish	3.71	0.45	3.35	0.46	0.19	82
Cauliflower:onion	3.89	0.42	3.42	0.42	0.18	86
2001						
Cauliflower	3.28 NS	0.45 NS	2.87 NS	0.32 NS	0.21 NS	93 NS
Cauliflower:bean	3.29	0.41	2.76	0.29	0.21	85
Cauliflower:cos lettuce	3.11	0.43	2.82	0.32	0.16	84
Cauliflower:leaf lettuce	3.15	0.44	2.76	0.32	0.17	92
Cauliflower:radish	3.17	0.43	2.74	0.31	0.17	87
Cauliflower:onion	3.13	0.42	2.74	0.31	0.15	87
2002						
Cauliflower	3.33 NS	0.36 NS	2.75 NS	0.42 NS	0.22 NS	81 NS
Cauliflower:bean	3.31	0.34	2.73	0.35	0.21	79
Cauliflower:cos lettuce	3.23	0.34	2.69	0.38	0.23	78
Cauliflower:leaf lettuce	3.27	0.38	2.71	0.42	0.24	76
Cauliflower:radish	3.28	0.35	2.65	0.36	0.21	82
Cauliflower:onion	3.28	0.37	2.64	0.40	0.23	80

NS: non significant.

Table 3
Yield of cauliflower in response to various intercropping systems

Cropping system	Curd yield (kg/ha)		
	2000	2001	2002
Cauliflower:bean	31703 a*	33111 NS	32567 a
Cauliflower:cos lettuce	31674 a	31111	31700 ab
Cauliflower:leaf lettuce	31926 a	33185	33400 a
Cauliflower:radish	29659 b	30948	30366 b
Cauliflower:onion	31867 a	32385	32667 a
Cauliflower sole	32904 a	33319	33366 a

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

and nonsoluble nutrients depends on the extent of root growth of component species. Complementary use of resources such as nutrients is likely to result when the intercrops explores a larger soil mass (Francis, 1989). Crops used with different root properties in this study could be exploited nutrients more efficient than sole.

3.3. *Yield*

The yield of cauliflower was not significantly affected when intercropped with cos lettuce, leaf lettuce, onion and bean in 2000–2002 (Table 3). These findings concur with the results of Brown et al. (1985) in tomato:cabbage, Natarjan (1992) in chilli:onion and Gliessman (1998) in broccoli:lettuce. Fukai and Trenbath (1993) reported that intercropping is most productive when intercrops differ greatly in growth duration so that their maximum requirements for growth resources occur at different times. In the study, the differences of growth rhythm, time of maturity or resource use of main and intercrops might be expected to reduce or postpone competition between crops. Moreover, after intercrops harvest, cauliflower may have taken full advantage of all available resources to complete its growth. Peirce (1987) and 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. They also pointed out that short duration vegetables can be harvested in time to make room for the later maturing ones.

In cauliflower:bean intercropping system, bean as an intercrop did not reduce also significantly yield of cauliflower (Table 3). This non-significant effect of bean as an intercrop on yield of cauliflower in this study was in agreement with the results of Poniedzialek et al. (1989); Sharma et al. (1988); Poniedzialek and Kunicki (1995) in cabbage:bean, Subhan (1991) in tomato:bean and of Itulya et al. (1997) in collard:cowpea intercrops. This may be attributed that intercropping with a legume can improve N-use (Itulya et al., 1997) and the legume can release biologically fixed N to the non-legume (Ofori and Stern, 1987). On the other hand, the ability of competition of bean may be lower than that of cauliflower because of its vigorous vegetative features.

Radish as an intercrop affected adversely yield of cauliflower (Table 3). Similar results were observed in cabbage intercropped with radish (Sharma et al., 1988; Varghese et al., 1990). Omar et al. (1989) reported that radish root exudates had the greatest effect in reducing the germination of cabbage which later reduced the growth. Kocacaliskan (2001) reported that radish with allelopathic effects can affect adversely growth and yield of other crops. These reports support in the results of the study.

3.4. *Intercropping efficiency*

When the values of land equivalent ratio appear to be greater than 1 under intercropping system, this usually indicates the efficiency of this system over the sole cropping system (Vandermeer, 1989). The land equivalent ratios as an indicator of biological efficiency in intercropping systems were always greater than 1 with intercropping in this study (Table 4). In the study the highest value of LER was obtained in cauliflower intercropped with leaf lettuce and gave a LER of 1.32, 1.35 and 1.36 in 2000–2002, respectively. The lowest LER values were determined in cauliflower:radish treatment as 1.07, 1.10 and 1.08, respectively. The high efficiency of intercropping found in this study agreed with the findings of Prabhakar and Shukla (1990), Malhotra and Kumar (1995); Costa and Perera (1998); Baumann et al. (2001), who explained this phenomenon by the complementary use of growth resources in vegetable production. An explanation for the beneficial effect of intercropping might be the more efficient use of available resources per unit area

Table 4
Land equivalent ratios and net income of cropping systems

Cropping system	Land equivalent ratio	Net income (∈/ha)
2000		
Cauliflower sole	1.00	11186
Cauliflower:bean	1.26	14508
Cauliflower:cos lettuce	1.24	16491
Cauliflower:leaf lettuce	1.32	11320
Cauliflower:onion	1.18	13186
Cauliflower:radish	1.07	10288
2001		
Cauliflower sole	1.00	5376
Cauliflower:bean	1.31	6768
Cauliflower:cos lettuce	1.22	7884
Cauliflower:leaf lettuce	1.35	5658
Cauliflower:onion	1.18	6175
Cauliflower:radish	1.10	5507
2002		
Cauliflower sole	1.00	7290
Cauliflower:bean	1.29	9021
Cauliflower:cos lettuce	1.25	10890
Cauliflower:leaf lettuce	1.36	7720
Cauliflower:onion	1.12	8436
Cauliflower:radish	1.08	7327

particularly when manure and water were provided in adequate quantities (Sharaiha and Hattar, 1993).

Willey (1979) reported that the practical significance of LER can only be fully assessed when related to the actual economic yield. Indeed, Muoneke and Asiegbu (1997) concluded that the highest LER values did not always reflect highest monetary return to the farmer. The sustainability of any production system is influenced by the economic returns, which determine the commercial feasibility of different intercropping systems. On the basis of prices and variable costs, which included labour but no cost of land, economic analysis of the results was made (Table 4). This study indicates that the most economically satisfactory intercropping system was obtained with cauliflower:cos lettuce treatment. In addition, leaf lettuce, bean or onion as an intercrop increased the net income compared to sole cauliflower while radish decreased in 2000 (Table 4). In the study it could be concluded that intercropping based on cauliflower could not only use limited areas for crop production more efficiently but also increase income for small farmers with limited resources. Higher returns under intercropping systems explained the suitability of intercropping systems to be adopted on a commercial scale. This positive effect of intercropping on net income in this study was in agreement with the results of Erdogan and Karatas (2000) in cucumber, pepper and tomato:lettuce, Abidin et al. (1989) in garlic:bean, Quayyum and Akanda (1990) in cabbage:bean, Prabhakar and Shukla (1991) in okra:bean intercrops.

4. 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 indicate that cauliflower intercropped with other vegetables like cos lettuce, leaf lettuce, bean or onion would be a remunerative cropping system which produced higher yields and economic returns when compared to a monocrop of cauliflower. This information will allow small, resource-poor farms to use their labour and inputs more efficiently.

It is worthy to investigate that the yield of intercrops can be raised without affecting the yield of the main crop (cauliflower).

Acknowledgements

We are very grateful to The Ataturk University, Scientific Research Projects Foundation for generous financial support (Project Number 2000/88) and to two anonymous referees for valuable comments on the manuscript.

References

Abidin, Z., Subhan, R., Basuki, R.S., 1989. Experiments on multiple cropping of garlic with red bean and red pepper. Hort. Abst. 59 (3), 1968.

Anonymous, 2002. Agricultural Structure (Production, Price, Value). Institute of Statistics, Prime Ministry Republic of Turkey.

Baumann, D.T., Bastiaans, L., Kropff, M.J., 2001. Competition and crop performance in a leek-celery intercropping system. Crop Sci. 41, 764–774.

Brown, J.E., Splittstoesser, W.E., Gerber, J.M., 1985. Production and economic returns of vegetable intercropping systems. J. Am. Soc. Hort. Sci. 110 (3), 350–353.

Coolman, R.M., Hoyt, G.D., 1993. Increasing sustainability by intercropping. Hort. Technol. 3, 309–311.

Costa, W.A.J.M., Perera, M.K.K.W., 1998. Effects of bean population and row arrangement on the productivity of chilli/dwarf bean intercropping in Sri Lanka. J. Agron. Crop Sci. 180 (1), 53–58.

Erdogan, H., Karatas, A., 2000. An investigation on intercropping production of tomato, cucumber and pepper together with crisphead and cos lettuce in heated glasshouse by geotermal energy. In: Proceedings of the Vegetable Symposium, 11–13 September, Isparta, Turkey, pp. 296–302.

Francis, C.A., 1989. Biological efficiences in multiple-cropping systems. Adv. Agron. 42, 1–42.

Frank, A.L., 1975. Basic Food Chemistry. The Avi Publishing Company Inc, Westport.

Fukai, S., Trenbath, B.R., 1993. Processes determining intercrop productivity and yields of component crops. Field Crops Res. 34, 247–271.

Gliessman, S.R., 1998. Agro-Ecological Processes in Sustainable Agriculture. Sleeping Bear Press, Chelsea, ML, USA.

Guvenc, I., Yildirim, E., 1999. Multiple cropping systems in vegetable production. In: Proceedings of the Organic Agriculture Symposium, 21–23 June, Izmir, Turkey, pp. 288–296.

Horwith, B., 1985. A role for intercropping in modern agriculture. BioScience 35, 5.

Itulya, F.M., Mwaja, V.N., Masiunas, J.B., 1997. Collard-cowpea intercrop response to nitrogen fertilization, redroot pigweed density, and collard harvest frequency. Hort. Sci. 32 (5), 850–853.

Jarenyama, P., Hesterman, O.B., Waddington, S.R., Harwood, R.R., 2000. Relay-intercropping of sunnhemp and cowpea into a smallholder maize system in Zimbabwe. Agron. J. 92, 239–244.

Kacar, B., 1972. Bitki ve Topraǧýn Kimyasal Analizleri II. Bitki Analizleri. Ankara Üniversitesi Ziraaat Fakültesi Yayýnlarý No: 453., Ankara.

Kocacaliskan, I., 2001. Allelopathy. Department of Biology, Dumlupýnar University, Kütahya, Turkey, p. 132.

Malhotra, S., Kumar, N., 1995. Performance of potato vegetables intercropping systems under dry-temperate conditions of north-western Himalayas. Indian J. Agron. 40 (3), 394–397.

Midmore, D.J., 1993. Agronomic modification of resource use and intercrop productivity. Field Crops Res. 34, 357–380.

Morris, R.A., Garrity, D.P., 1993. Resource capture and utilization in intercropping: non-nitrogen nutrients. Field Crops Res. 34, 319–334.

Muoneke, C.O., Asiegbu, J.E., 1997. Effect of okra planting density and spatial arrangement in intercrop with maize on the growth and yield of the component species. J. Agron. Crop Sci. 179 (4), 201–207.

Natarjan, S., 1992. Effects of intercrops on chilli (*Capsicum annuum* L.) under semi dry conditions. South Indian Hortic. 40 (5), 273–276.

Ofori, F., Stern, W.R., 1987. Cereal-legume intercropping systems. Adv. Agron. 41, 41–89.

Olasantan, F.O., 1991. Response of tomato and okra to nitrogen fertilizer in sole cropping and intercropping with cowpea. Hort. Sci. 66, 191–199.

Omar, N.M., Gomaa, H.M., Bhairy, A.G., Ali, A.H., 1989. Seed germination and seedling growth of tomato as affected by root exudates of cabbage, cauliflower and radish. Egypt. J. Hortic. 6 (2), 165–171.

Peirce, L.C., 1987. Vegetables. Characteristics, Production and Marketing. Willey, New York, USA, p. 433.

Poniedzialek, M., Zacharias, A., Kunucki, E., Suchodolska, R., 1989. Effect of cabbage, french bean and snap bean intercropping on the level and quality of yield. Folia Horticulturae 1 (2), 37–51.

Poniedzialek, M., Kunicki, E., 1995. The Suitability of several french bean cultivars for late maturing cabbage intercropping. Ogrodnictwo 22, 5–16.

Prabhakar, B.S., Shukla, V., 1990. Crop land use efficiency in sequential intercropping systems with vegetables. Indian J. Hort. 47 (4), 427–430.

Prabhakar, B.S., Shukla, V., 1991. Crop land use effciency sequential intercropping systems with vegetables. Hort. Abst. 61 (9), 7856.

Quayyum, M.A., Akanda, M.E.M., 1990. Productivity and profitability of cabbage intercropped vegetables. Hort. Abst. 60 (9), 7201.

Santos, R.H.S., Gliessman, S.R., Cecon, P.R., 2002. Crop Interactions in broccoli intercropping. Biol. Agric. Hortic. 20, 51–75.

Sharaiha, R.K., Hattar, B., 1993. Intercropping and poultry manure effects on yields of corn, watermelon and soybean grown in a calcareous soil in the Jordan Valley. J. Agron. Crop Sci. 171, 260–267.

Sharma, R.P., Patil, R.R., Arora, P.N., 1988. Spatial arrangement and methods of planting in cabbage (*Brassica oleracea* convar. *capitata* var. c*apitata)* intercropping. Indian J. Agric. Sci. 58 (9), 673–677.

Shultz, B., McGuinness, H., Horwith, B., Vandermeer, J., Phillips, C., Perfecto, I., Rosset, P., Ambrose, R., Hansen, M., 1987. Effect of planting densities, irrigation, and hornworm larvae on yields in experimental intercrops of tomatoes and cucumbers. J. Am. Soc. Hort. Sci. 112 (5), 747–755.

Splitstoesser, W.E., 1990. Vegetable Growing Handbook. Van Nostrand Reinhold, New York, USA, p. 362.

Subhan, I., 1991. Effect of intercropping with *Phaseolus vulgaris* L. on growth and yield of tomato *Solanum lycopersicum* L. Hort. Abstr. 61 (4), 2863.

Theunnissen, J., 1997. Intercropping in field vegetables as an approach to sustainable horticulture. Outlook Agric. 26 (2), 95–99.

Vandermeer, J., 1989. The Ecology of Intercropping. Cambridge University Press, Cambridge, UK, p. 237

Varghese, L.T., Umale, S.B., Kawthalar, M.P., 1990. Effect of intercrops on the growth and yield of cabbage. South Indian Hortic. 38 (4), 196–198.

Varghese, L., 2000. Indicators of production sustainability in intercropped vegetable farming on montmorillonitic soils in India. J. Sustain. Agric. 16 (4), 5–17.

Willey, R.W., 1979. Intercropping—its importance and yield advantages. Field Crops Abstr. 32 (1), 1–10.

Woolley, J., Davis J.H.C., 1991. The agronomy of intercropping with beans. In: Schoonhoven, A., Oyset, M. (Eds.), Common Beans: Research for Crop Improvement. CAB International, Colombia, 980 p.

Zhou, X., Madramootoo, C.A., MacKenzie, A.F., Kaluli, J.W., Smith, D.L., 2000. Corn yield and fertilizer N recovery in water-table-controlled corn-rye-grass systems. Europ. J. Agron. 12, 83–92.