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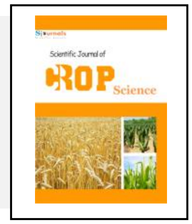

Review article

Review of intercropping research: Studies on cereal-vegetable based cropping system

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A B S T R A C T

Intercropping which is closely associated with peasant agriculture is a practice that involves the growth of two or more crops in proximity, in the same field during a growing season to promote interactions between them. Reasons for this practice include insurance against total crop failure, yield increment, weed control and high monetary returns. Studies on crop mixture have recently focused on cereal-vegetable intercropping system, such as maize-okra, maize-tomato, maize-leafy green, maize-egusi melon, maize-cauliflower amongst others. This paper, which is a compilation of reviewed reports, generally examined the areas of consideration in intercropping, it discussed the benefits obtained and broadly assessed the yield advantages derived from intercropping, with particular reference to cereal-vegetable based cropping system. The compilation of the reviewed reports, therefore serves as useful information base for other agricultural scientists with interest in the area of intercropping research, with particular focus on cereal-vegetable mixture.

1. Introduction

Intercropping is a type of mixed cropping and defined as the agricultural practice of cultivating two or more crops in the same space at the same time (Hugar and Palled, 2008). The important reason to grow two or more crops together is the increase in productivity per unit area of land in intercropping system (Langert *et al.,* 2006).

Intercropping with cereal crop such as maize in tropical regions is a way to grow a staple crop while obtaining several benefits from the additional crop. It is the most appropriate cropping system for maintenance of soil productivity in the tropics (Ijoyah and Dzer, 2012), and ensures good soil cover throughout the year (Beets, 1990). These practices have been so interwoven in the socio-economic lives of peasant farmers (Sadashiy, 2004). The reason for the persistence of this practice is not only that gross returns per unit area of land are usually higher under intercropping than in sole cropping (Brintha and Seran, 2009), the system also offers the farmers insurance against crop failure, helps control erosion, weeds and insect infestation and brings about a more distribution of farm labour than sole cropping (Ali *et al.,* 2000). There are also some socio-economic, biological and ecological advantages in intercropping over monocropping (Maluleke *et al.,* 2005).

Several scientists have worked on cereal based intercropping, such as maize-bean, maize-potato, maize-cassava, maize-yam, maize-soybean, maize-groundnut, amongst many others (Ifenkwe *et al.,* 1989; Mutsaers *et al.,* 1993; Tsubo *et al.,* 2005; Jiao *et al.,* 2008 and Ijoyah and Fanen, 2012). Studies on intercropping have recently focused on cereal-vegetable mixture (Langert *et al.,* 2006; Hugar and Palled, 2008; Ijoyah and Jimba, 2012; Ijoyah *et al.,* 2012b). The objective of this paper, is to put together review of works carried out by researchers, particularly on cereal-vegetable based intercropping, which could be useful for other agricultural scientists that would want to research in the area.

2. Considerations in intercropping system

Successful intercropping needs several considerations before and during cultivation. Such considerations include the following:

2.1. Maturity of crops

When two or more crops are grown together, ensure that the peak period of growth of component crops do not coincide. The biggest yield advantage and complementary effects occur when component crops have different growing periods to make their major demands on resources at different times. Crops which mature at different times have their own separate periods to make maximum demands on nutrient, light and moisture needs. Such crops should be suitably intercropped (Reddy and Reddi, 2007).

2.2. Time of planting

Cereal crop such as maize, have been recognized as a common component in most intercropping systems. It seems to dominate as the cereal component of intercrop and often combined with other crops (Maluleke *et al.,* 2005). It is the third most important cereal crop following wheat and rice in the world production and used as food, feed and forage (Kamara *et al.,* 2005).

Intercropping with maize is a way to grow a staple crop while obtaining several benefits from the additional crop. Ijoyah and Dzer (2012) in an experiment to evaluate the yield of maize in a maize-okra mixture as affected by time of planting maize, reported that the greatest intercropped yield of maize was obtained when maize was planted at same time as okra (Table 1). This result agreed with Muoneke and Asiegbu (1997) who reported that best intercropped maize yield was obtained when planting was done at the same time as okra in a maize-okra mixture (Table 1). Ijoyah and Dzer (2012) also reported that intercropping maize and okra at same time produced the best okra yield compared to that obtained from monocropped okra (Table 1). Mongi *et al.,* (1976) found out that planting maize with cowpea at the same time gave better maize yield (Table 1). This view, however contradict that of Amede and Nigatu (2001) and Ijoyah and Jimba (2011) who reported that yields of maize and okra were not significantly ($P \leq 0.05$) affected when planted at the same time with sweet potato in a sweet potato-maize or sweet potato-okra mixture (Table 1). They attributed this to the different peak periods of the component crops in making maximum demands on growth resources.

2.3. Plant density

Low plant population per unit area leads to low yields (Jeyakumaran and Seran, 2007). If full rates of each crop were planted, neither would yield well because of intense overcrowding. By reducing the seedling rate of each, the crops could have a chance to yield well within the mixture. Ijoyah *et al.,* (2012a) reported that increasing intra-row spacing of maize up to 30 cm gave the greatest intercrop yields of maize and egusi melon and highest land equivalent ratio values in a maize-egusi melon intercropping system. In maize-okra intercropping, high plant density reduced number of okra leaves due to competition for light and other resources (Muoneke and Asiegbu, 1997). Ijoyah *et al.,* (2012a) reported that in a maize-okra mixture, increasing maize plant density up to 50,000 plants per hectare reduced intercropped okra yield, but significantly ($P \le 0.05$) increased intercropped maize yield. They also reported that maize sown at 50,000 plants per hectare not only recorded the lowest competitive pressure but gave the highest land equivalent ratio (LER) values of 1.83 and 1.86 respectively, in years 2010 and 2011 (Table 2), thus, indicating that the greatest productivity per unit area was achieved by growing the two crops together at maize population density of 50,000 plants per hectare, than by growing them separately. Wuhua (1985) in his experiment in Ibadan, Nigeria, designed to determine how yields, yield components and other growth parameters of melon and maize change in mixture as melon population density increased, reported that melon biomass and seed yield increased linearly with population density in mixed and pure stands. Intercropping reduced melon seed yield but did not affect seed size. He concluded that for weed and erosion control and increased total yields, maize could be intercropped with melon up to 20,000 plants per hectare of melon with 40,000 plants per hectare of maize. Similarly, Olasantan and Lucas (1992) in their study on intercropping maize with other crops of different canopy heights (maize/okra, maize/leafy green, maize/melon), reported that intercropped maize had greater effect on melon, as melon in the mixture with maize, apart from the ground competition, experienced overhead shading from maize, thus, reducing the amount of solar radiation available for phothosynthesis. A plant receiving less energy than usual would produce fewer branches.

The number of leaves per plant might increase to sustain the plant until a population was attained where there would not be enough resources to support the leaves already initiated. As population density increased up to a certain limit beyond which mutual shading of leaves could have reduced the amount of energy available for leaf expansion, many of the leaves would be respiring more than they photosynthesize. Hence in a mixture of maize-melon, leaf area (LA) would not increase linearly with population density as it could have been in pure stands. Olasantan and Lucas (1992) observed that by the 9th week after planting (WAP) melon and maize as intercrops, production of branches and leaves of melon were significantly ($P \le 0.05$) reduced, but the stems of intercropped melon were longer than in the sole cropped plant. On grain yield of maize in a maize-melon intercrop, it was reported that sole cropped maize produced the highest grain yield but this was significantly ($P \le 0.05$) reduced when grown with melon. Melon grown alone produced significantly ($P \le 0.05$) greater number of seed per fruit and higher seed yield per hectare than those intercropped with maize.

2.4. Compatible crops

In intercropping, choosing of the crop combination plays a vital role. In compatibility, factors such as planting density, rooting system, shading and nutrient competition need to be considered (Ijoyah and Fanen, 2012; Ijoyah and Jimba, 2012). Plant competition could be minimized not only by spatial arrangement but also by choosing crops that are able to exploit soil nutrients. Examples of such compatible crops include the mixture of maize-okra, maize-tomato, maize-egusi melon, and maize-cauliflower.

3. Benefits of intercropping

3.1. Resource utilization

The main reason for higher yields in intercropping is that the component crops are able to make better overall use of natural resources than grown separately (Willey, 1979). The efficient use of basic resources in the cropping system depends partly on the inherent efficiency of the individual crops that make up the system and partly on complimentary effects between the crops (Willey and Reddy, 1981).

Numbers of pods per okra plant were lower in maize-okra intercropping compared to monocropping due to nutrients and light competition (Ijoyah and Jimba, 2012). Different root and leaf systems are able to harness more light and make use of more water and nutrients than when the roots and leaves of only one species are present. Intercropping between high and low canopy crops is a common practice in tropical agriculture, and to improve light interception and yields of the shorter crops requires that they be planted between sufficiently wider rows of the taller plants.

Table 1
Intercrop yields, total intercrop yields and land equivalent ratios of component crops in a cereal based cropping system as affected by time of planting.

Cereal based cropping system	Experiment	Best Treatment	Intercrop yield of maize (t ha^{-1})	Intercrop yield (t ha^{-1}) of component crop	Total intercrop yield (t ha^{-1})	LER	Reference
Maize - Okra	Time of planting	MO (same time)	4.4	4.8	9.2	0.92	(Ijoyah and Dzer, 2012)
Maize - Okra	Time of planting	MO (same time)	3.1	4.3	7.4	0.72	(Muoneke and Asiegbu, 997)
Maize - Cowpea	Time of planting	MC (same time)	3.2	3.9	7.1	0.82	(Mongi *et al*., 1976)
Maize – Sweet Potato	Time of planting	MS (same time)	Ns	Ns	12.4	0.75	(Amede and Nigatu, 2001)

MO: maize and okra planted at same time MC: maize and cowpea planted at same time MS: maize and sweetpotato planted at same time
Ns: not significant

Table 2
Yield advantage indicators in a cereal-vegetable intercropping system under different studies.

Crops in mixture	Studies	LER		Percentage (%) Land Saved		CR		Reference
		2009	**2010**	**2009**	**2010**	**2009**	**2010**	
Maize - Okra	Intercropping	1.84	1.80	45.7	44.4	1.42	1.40	(Ijoyah and Jimba, 2012)
		2010	**2011**	**2010**	**2011**	**2010**	**2011**	
Maize - Okra	Population densities	1.83	1.86	45.4	46.2	0.65	0.65	(Ijoyah *et al*., 2012a)
		1995	**1996**	**1995**	**1996**	**1995**	**1996**	
Maize - Tomato	Intercropping	1.68	1.60	50.2	48.4	1.20	1.15	(Sharma and Tiwari 1996)
		1999	**2000**	**1999**	**2000**	**1999**	**2000**	
Maize – Cauliflower	Intercropping	1.50	1.40	50.8	48.2	1.43	1.42	(Khatiwada, 2000)
		2010	**2011**	**2010**	**2011**	**2010**	**2011**	
Maize – Egusi melon	Intra-row spacing	1.80	1.76	44.4	43.2	1.50	1.55	(Ijoyah *et al*., 2012b)

LER: Land equivalent ratio
CR: Competitive ratio

Ijoyah *et al.,* (2012b) found maize-egusi melon intercropping enhanced the efficient utilization of strong light by maize and weak light by egusi melon. Jeyakumaran and Seran (2007) reported that when two morphologically dissimilar crops with different periods of maturity are intercropped, light is the vital factor that determines yield.

Improvement of water use efficiency in intercropping leads to increase in the use of other resources (Hook and Gascho, 1988). Intercrops have been identified to conserve water largely because of early high leaf area (Ogindo and Walker, 2005). Various root systems in the soil reduces water loss, increases water uptake, creating a cooler microclimate of the surrounding (Innis, 1997). Barhom (2001) reported that water use efficiency was higher under intercropping compared to monocropping.

3.2. Weed control

The nature and magnitude of crop-weed competition differs considerably between monocrop and intercrop combinations. Crop-weed competition is determined by growth habit of crop (Dimitrios *et al.,* 2010). Increased leaf cover in intercropping system helps to reduce weed populations once the crops are established (Beets, 1990). Makinde (2009) and Ijoyah and Dzer (2012) reported that leafy greens and okra can be intercropped with maize to control weeds and increase productivity. Intercropping maize with vegetables such as okra, egusi melon and leafy green considerably reduced the weed density compared with the monocropped maize by decrease in available light for weeds (Dimitrios et al., 2010).

3.3. Pests and diseases

Maize is susceptible to many pests and diseases (Drinwater *et al.,* 2002). Intercropping promises to be a very promising cultural practice in the reduction and control of pests and diseases. One component crop of an intercropping system may act as a barrier against the spread of pest and diseases. Trenbath (1993) reported that pest and diseases were high in monocropping compared to intercropping. Pino *et al.,* (1994) also reported that pest and disease were less in maize-tomato intercropping compared to tomato alone.

3.4. Economic benefits

Intercropping occupies greater land use and provides higher net returns (Brintha and Seran, 2009). It provides higher cash return than growing one crop alone (Kurata, 1986). Ijoyah and Dzer (2012) also reported that intercropping gave greater combined yields and monetary returns than those obtained from either crop grown alone. Intercropping maize and cauliflower gave high net return compared to monocropping (Khatiwada, 2000). Sharma and Tiwari (1996) also reported that maize intercropped with tomato increased total intercropped yields and gave greater monetary returns than those obtained from the component crops grown as sole.

4. Yield advantages in intercropping

4.1. Land equivalent ratio (LER)

When two crops are grown together, yield advantages occur because of differences in their use of resources (Willey *et al.,* 1983). Land equivalent ratio (LER) is the most common index adopted in intercropping to measure the land productivity. It is often used as an indicator to determine the efficacy of intercropping (Brintha and Seran, 2009).

LER is a standardized index that is defined as the relative area required by sole crops to produce the same yield as intercrops (Mead and Willey, 1980). It is formulated as follows:

$$\text{LER} = \frac{\text{Intercrop yield of crop A}}{\text{Sole crop yield of A}} + \frac{\text{Intercrop yield of crop B}}{\text{Sole crop yield of B}}$$

LER value greater than one indicates greater efficiency of land utilization in intercropping system.

The yield advantage indicators in a cereal-vegetable intercropping system under different studies are shown in Table 2. Maize-okra intercropping gave LER values of 1.84 and 1.80 respectively, in years 2009 and 2010 (Ijoyah and Jimba, 2012). Maize sown at 50,000 plants per hectare into okra plots gave the highest LER values of 1.83 and 1.86 respectively, in years 2010 and 2011 (Ijoyah *et al.,* 2012a). Maize-egusi melon intercropping gave LER values of 1.80 and 1.76 respectively, in years 2010 and 2011 (Ijoyah *et al*., 2012b), while Khatiwada (2000) reported LER values of 1.50 and 1.40 respectively, in years 1999 and 2000, in a maize-cauliflower intercropping system. Sharma and Tiwari (1996) also reported LER values of 1.68 and 1.60 in a maize-tomato intercropping system (Table 2). Ijoyah and Dzer (2012) reported that LER increased to a maximum of 45 % by intercropping maize with okra compared with the sole crop.

4.2. Percentage (%) land saved

The percentage (%) land saved as described by Willey (1985) is another index used in assessing the advantage of intercropping system. It indicates the amount of land saved from intercropping, and which could be used for other agricultural purposes. It is formulated as:

100- 1/LER x 100. Ijoyah *et al.*, (2012a) reported that 45.4 % and 46.2 % of lands were respectively saved in years 2010 and 2011 varying maize plant densities up to 50,000 plants per hectare in a maize-okra intercropping system (Table 2). Khatiwada (2000) also reported that 50.8% and 48.2 % of lands were respectively saved in 1999 and 2000, intercropping maize and cauliflower. Similarly, 44.4 % and 43.2 % of lands were respectively saved in 2010 and 2011, varying intra-row spacing of maize up to 30 cm in a maize-egusi melon intercrop (Table 2).

4.3. Competitive ratio (CR)

Since intercropping involves growing two or more crops together on the same land area, the question of competition between the crops arises. CR measures the degree of competition between the components of the intercrop (Willey and Rao, 1980). They proposed a measure that expresses the ultimate yields of the components corrected for the proportional areas on which the crops were sown. This measure is formulated as: CR= La/Lb, where La and Lb are the partial LERs of component crops. The competitive ratios were recorded higher for the different studies under intercropping (Table 2).

5. Conclusion

From the reviewed results obtained, it can be concluded that it is advantageous intercropping cereals with vegetable crops. This is associated with greater intercropped yields, higher land equivalent ratio values greater than 1.0, greater percentage of land saved and greater monetary returns. Cereal-vegetable intercropping system was therefore found to be highly complementary and suitable in mixture.

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