International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 10, No. 3, p. 275-282, 2017

RESEARCH PAPER OPEN ACCESS

Assessing the land equivalent ratio (LER) of maize (*Zea mays* L.) intercropped with *Rhizobium* inoculated soybean (*Glycine max* [L.] Merr.) at various P and K levels

Daniel Nyoki, Patrick A. Ndakidemi*

School of Life Science and Bio-engineering, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania

Key words: Legumes, Cereals, Intercropping, Monoculture, Biological nitrogen fixation, Yield advantage

http://dx.doi.org/10.12692/ijb/10.3.275-282 Article published on March 31, 2017

Abstract

A 2 years field experiment was carried out in northern Tanzania with the aim of assessing the effects of maize-soybean intercropping systems, *Rhizobium* inoculation and P and K supplementation on Land Equivalent Ratio. A three replicate experiment was laid out in a split-split plot design with the main plots comprised of Rhizobia inoculation (with and without). The sub plots comprised of three cropping systems and the sub-sub plots having seven fertilizer levels (kg ha^{-1}): Control, 20, 40 K, 26, 52 P, 26 P + 20 K and 52 P + 40 K. The results indicated that compared with pure stand, intercropping maize with soybean was advantageous because all the values of LER were above 1.0. Supplementation of inputs such as *Rhizobium* inoculants and P and K fertilizers significantly ($p<0.05$) increased the LERs over the control. The rhizobial inoculated plots gave the highest LER of 1.73 and 1.61 grain and biological yield compared with un-inoculated plots which gave the lowest LER of 1.31 and 1.39 grain and biological yield respectively. P and K also significantly increased LER over the control. When compared with the narrower spacing, wider spacing of soybean resulted to a greater LER values suggesting the use of wider spacing for legume-cereals intercropping. Hence, this study suggests that farmers should be advised to intercrop maize with soybean at a recommended spacing, and supplying with the recommended inputs above. However, application of P and K fertilizers will depend on the fertility status of the soil in respective area under consideration.

* **Corresponding Author:** Patrick A. Ndakidemi ✉ ndakidemipa@gmail.com

Introduction

In agro ecosystems, intercropping allows better resource use efficiency hence reducing the needs for external inputs and moving towards agricultural sustainability (Beets, 1994; Dariush *et al*., 2006). It is a practice of growing two or more crops in the same piece of land at the same time (Sanchez, 1976). It plays an important role in subsistence food production in developing countries (Tsubo *et al*., 2005). It is has been well established that intercropping offers so many potential advantages such as: improved utilization of growth resources by the intercropped species (Banik *et al*., 2006); direct nitrogen transfer from legumes to cereals in intercropping (Giller and Wilson, 1991); Enhanced productivity due to nitrogen fixation (Maingi *et al*., 2001; Banik *et al*., 2006); used as a method of controlling weeds, insect pests, diseases (Smith and Mcsorley, 2000) and control of soil erosion (Jabbar *et al*., 2009; Matusso *et al*., 2012). However, intercropping may results in positive interactions (facilitations) or negative interactions (competitions) of the intercropped crop components. Positive interaction is good because the component crops under intercropping facilitate each other to achieve maximum yielding or productivity (Ghaffarzadeh *et al*., 1994; Ghosh, 2004; Knudsen *et al*., 2004). On the other hand, a negative interaction reduces the yield of the less competitive crops in intercropping. There are many indices/methods that have been developed to assessing these interactions in intercropping. These includes: relative crowding coefficient (RCC) (Gosh, 2004), competitive ratio (CR) (Willey and Rao (1980), land equivalent ratio (LER) (Mead and Willey, 1980), aggressivity (A) (McGilchrist and Trenbath, 1971), and monetary advantage index (MAI) (Gosh 2004).

Of these indices, the LER is mostly preferred and used index for comparisons of intercrop versus sole crop (Agegnehu, 2006; Esmaeili *et al*., 2011). LER is an accurate method of assessing the competitive relationship between the intercropped crops, and the overall productivity of intercropping system (Zada *et al*., 1988). It also measures how efficient are intercropping, it compares land areas required under monoculture or sole cropping to give the same yields as that obtained from the component crops of the intercrop (Federer and Schwager, 1982; Ndakidemi and Dakora, 2007; Brintha and Seran, 2009; Nyoki and Ndakidemi, 2016).

Based on the advantages of using LER in comparing intercropped crops, this study focused on LER as an index of assessing overall productivity and comparing intercropped crops. According to Gliessman (2007), the total LER of the intercropped crops should be 1.0 and their partial LER should be 0.5 for each crop if the intercropped crops have the same agro-ecological characteristic. The resulting number from LER is a ratio that indicates the amount of land required to grow both crops together relative to the amount of land needed to grow sole crop of each and give the same yield (Amanullah *et al*., 2016).

The LER with value greater than 1.0 indicates that intercropping is advantageous while the LER less than 1.0 shows that intercropping is disadvantageous (Dariush *et al*., 2006; Mohammed, 2011). For instance, a LER 1.25 indicates that an area planted sole crop or monoculture, would require 25% more land to produce the same yield as the same area planted in an intercrop (Laster and Furr, 1972; Dariush *et al*., 2006). On the other hand the LER of 0.75 shows that the yield of intercropped crops was only 75% of the yield of pure stand. Regardless of the yield advantages in intercropping, there is little information on how variation and combination of inputs such as *Rhizobium* inoculants and P and K fertilizers may influence the yield advantages in intercropping over sole cropping.

The objective of the current study was to assess the land equivalent ratio of the maize intercropped with soybean at different soybean spacing under Rhizobia inoculation and different levels of singly applied and combined P and K.

Material and methods

Experimental Design and Treatments

The field experiment was conducted for two consecutive years (2015 and 2016 cropping seasons).

The experiment was carried out at Tanzania Coffee Research Institute (TaCRI) farm in northern Tanzania. The experiment was laid out in split-split plot design with factorial arrangement and replicated thrice. The plot measured 3 x 3 m.

The main plots had two Rhizobia inoculation treatments, while the sub plots comprised the following treatments; Maize (sole crop) at a spacing of 75 x 60 cm; Soybean (sole crop) at a spacing of 75 x 40 cm; Maize/soybean (intercropping system) at a spacing of 75 x 60 cm and 75 x 20 cm, Maize and soybean respectively; and the last cropping system was Maize/soybean (intercropping system) at a spacing of 75 x 60 cm and 75 x 40 cm, Maize and soybean respectively. The sub-subplots were treated with the following fertilizer levels (kg ha^{-1}): control; 20 K; 40 K; 26 P; 52 P; 26 P + 20 K; 52 P + 40 K. The sources of these elements were TSP for P and MOP for K

Data collection

At physiological maturity, the plants in the middle rows of each plot were counted and harvested for assessing grain yield and yield components of both soybean and maize. For yield components, 10 plants of both crops were sub-sampled from each plot to determine the biological yield in both soybean and maize. All pods and cobs from each plot were manually threshed separately and allowed to dry to 13% moisture content for determination of gain yield.

Determination of Land Equivalent Ratio (LER)

The LER of grain and biological yield of maize and soybean was assessed in this study. Intercropping was assessed, relative to sole crops, by use of Land Equivalent Ratios (LERs), which is referred to as the proportion/amount of land area that is needed for sole cropping to produce the same yield as the intercropping (Mead and Willey, 1980). The following formula was used to calculate the LER.

$$LER = L1 + L2 = \frac{YI1}{YS1} + \frac{YI2}{YS2}$$

L1 and L2 are the LERs for the individual crops (soybean and Maize), (YI1 and YI2 are the individual crop yields in intercropping, where YS1 and YS2 are their yields as sole crops.

The partial LERs (L1 and L2) were then summed up to give the total LER for the intercrop.

Statistical analysis

The collected data was analysed using statistical software called STATISTICA. The statistical analysis was performed using analysis of variance (ANOVA) in factorial arrangement. The fisher's least significance difference (L.S.D.) was used to compare treatment means at p = 0.05 level of significance (Steel and Torrie, 1980)

Results

LER for grain yield

Statistical analysis of the data showed that combination of Rhizobia inoculation, intercropping systems and P and K fertilization had significant effects on LER for the two cropping seasons (Table 1). A LER was significantly higher in plots that were inoculated with Rhizobia relative to un-inoculated plots for the two consecutive years. It is well shown in Table 1 that intercropping at different spacing had significant effects on LER. The narrower spacing of M+B(A) produced lower total LER compared with the wider spacing of M+B(B) which produced significantly higher LER (Table 1). The highest Total LER of 1.73 was obtained in Rhizobium inoculated plot and intercropping at wider spacing of M+B(B) in 2015 cropping season while the lowest total LER of 1.31 was obtained at intercropping with narrower spacing of M+B(A) without Rhizobia inoculation (Table 1). The results of this study further indicated that P and K fertilization also significantly increased the values of LER over the control. The highest LERs (1.48) were recorded in plots treated with 40 K and 20 K + 26 P for 2015 cropping season at a narrower spacing. In the same season, the wider spacing gave the highest LER of 1.57 recorded from 26 P and 40 K + 52 P (kg ha^{-1}) (Table 1). In the second cropping season, the highest LER of 1.59 was recorded from plots treated with 40 K and 40 K + 52 P (kg ha^{-1}) at narrower spacing of M+B(A). The wider spacing of intercropping produced significantly higher (1.68) LER which was found in plots treated with 40 kg of K per hectare. Regardless of the cropping season and the spacing applied under intercropping, lowest LERs were recorded in the control plots (Table 1).

Table 1. Partial and Total LER for grain yield of Soybean and Maize for 2015 and 2016 cropping season as affected by varied spacing, Rhizobia inoculation and P and K fertilization.

Treatment	2015 cropping season						2016 cropping season					
	Partial LER at M+B(A)		Total LER	Partial LER at M+B(B)		Total LER	Partial LER at M+B(A)		Total LER	Partial LER at M+B(B)		Total LER
	Soybean	Maize		Soybean	Maize		Soybean	Maize		Soybean	Maize	
Rhizobia												
With out	0.66	0.69	1.35b	0.78	0.71	1.49b	0.66	0.65	1.31b	0.69	0.66	1.35b
With	0.80	0.74	1.54a	0.94	0.79	1.73a	0.75	0.68	1.43a	0.86	0.72	1.58a
Fertilizers (kg ha^{-1})												
Control	0.65	0.68	1.33e	0.76	0.62	1.38d	0.73	0.69	1.42e	0.59	0.65	1.24f
20K	0.67	0.68	1.35d	0.70	0.75	1.45c	0.87	0.65	1.52c	0.85	0.69	1.54d
40K	0.70	0.78	1.48a	0.70	0.79	1.49b	0.90	0.69	1.59a	0.97	0.71	1.68a
26P	0.70	0.73	1.43b	0.82	0.75	1.57a	0.74	0.75	1.49d	0.82	0.7	1.52d
52P	0.69	0.69	1.38c	0.85	0.71	1.56a	0.80	0.76	1.56b	0.87	0.74	1.61b
20K+26P	0.89	0.59	1.48a	0.78	0.69	1.47bc	0.78	0.64	1.42e	0.89	0.67	1.56c
40K+52P	0.74	0.73	1.47a	0.84	0.73	1.57a	0.72	0.87	1.59a	0.76	0.66	1.42e
Level of significant												
Rhizobia			***			***			***			***
Fertilizers			***			***			***			***

LER: Land Equivalent Ratio, M+B (A): Maize/soybean intercropped at a spacing of 75 x 60 cm and 75 x 20 cm, maize and soybean respectively; M+B (B): Maize/soybean intercropped at a spacing of 75 x 60 cm and 75 x 40 cm, maize and soybean respectively; Values presented are means; ***: significant at $p \leq 0.001$; Means followed by dissimilar letter(s) in a column are significantly different from each other at p=0.05 according to Fischer least significance difference (LSD).

LER for Biological yield

As for grain yield, the biological yield also resulted in greater LER values in plots inoculated with Rhizobia compared with un-inoculated treatments. When comparing intercrop spacing, and Rhizobia inoculation, the LER was higher (1.61) in Rhizobia inoculated plots and the lowest LER was 1.39 recorded in un-inoculated plots with wider spacing of intercrop in 2015 cropping season (Table 2). Furthermore, the current study has indicated that P and K significantly improved the total LER over the control (Table 2).

The highest total LER of 1.64 was recorded in plot treated with 26 kg of P and wider spacing of intercrop in the second cropping season. The lowest LER of 1.31 was recorded in control plots and both narrower and wider spacing of intercrop for the first cropping season.

Table 2. Partial and Total LER for biological yield of Soybean and Maize for 2015 and 2016 cropping seasons as affected by varied spacing, Rhizobia inoculation and P and K fertilization.

Treatment	2015 cropping season						2016 cropping season					
	Partial LER at M+B(A)		Total LER	Partial LER at M+B(B)		Total LER	Partial LER at M+B(A)		Total LER	Partial LER at M+B(B)		Total LER
	Soybean	Maize		Soybean	Maize		Soybean	Maize		Soybean	Maize	
Rhizobia												
With out	0.68	0.86	1.54b	0.66	0.73	1.39b	0.76	0.72	1.48b	0.75	0.76	1.51b
With	0.71	0.89	1.60a	0.82	0.79	1.61a	0.76	0.78	1.54a	0.74	0.84	1.58a
Fertilizers (kg ha^{-1})												
Control	0.61	0.70	1.31d	0.60	0.71	1.31e	0.72	0.67	1.39c	0.54	0.81	1.35e
20K	0.74	0.78	1.52c	0.65	0.76	1.41d	0.70	0.73	1.43cb	0.79	0.78	1.57b
40K	0.69	0.86	1.55b	0.81	0.73	1.54b	0.71	0.75	1.46b	0.62	0.86	1.48d
26P	0.73	0.88	1.61a	0.75	0.79	1.54b	0.69	0.83	1.52a	0.78	0.86	1.64a
52P	0.76	0.85	1.61a	0.8	0.69	1.49c	0.81	0.73	1.54a	0.81	0.77	1.58b
20K+26P	0.68	0.91	1.59a	0.76	0.73	1.49c	0.62	0.81	1.43cb	0.78	0.75	1.53c
40K+52P	0.69	0.87	1.56b	0.8	0.81	1.61a	0.72	0.74	1.45b	0.83	0.79	1.62a
Level of significant												
Rhizobia			***			***			***			***
Fertilizers			***			***			**			***

LER: Land Equivalent Ratio, M+B (A): Maize/soybean intercropped at a spacing of 75 x 60 cm and 75 x 20 cm, maize and soybean respectively; M+B (B): Maize/soybean intercropped at a spacing of 75 x 60 cm and 75 x 40 cm, maize and soybean respectively; Values presented are means; **, ***: significant at $p \leq 0.01$, $p \leq 0.001$ respectively; Means followed by dissimilar letter(s) in a column are significantly different from each other at p=0.05 according to Fischer least significance difference (LSD).

Discussion

The results of the current study has proved that growing two or more crops in a piece of land at the same time, is advantageous and farmer who practice intercropping gets more crops compared with the one growing sole crops. The yield advantage in intercropping is indicated by the LER greater than 1.0 (Esmaeili *et al*., 2011). From the results above, all the total LERs were greater than 1 notifying that there was a yield advantage in intercropping relative to mono culture (Dariush *et al*., 2006; Esmaeili *et al*., 2011). Interestingly, Rhizobia inoculation and P and K fertilization significantly increased the total LERs of both grain and biological yield over the control. This shows the necessity of these inputs in the study area when the crops are intercropped. For the two cropping seasons, wider spacing intercrop under Rhizobia inoculation significantly increased the total LERs of grain yield by 24 and 23% over narrower spacing which increased total LERs by 19 and 12% for the 2015 and 2016 cropping seasons respectively. Moreover, there was a significant biological yield advantage of 6% in inoculated plots with narrower spacing over un-inoculated plots for the two cropping seasons. The wider spacing and Rhizobia inoculation resulted in yield advantage of 22 and 7% for first and second cropping seasons respectively. In general, the Rhizobia inoculated plots with wider spacing of intercrop gave 73% grain yield advantage of intercrop over sole cropping in 2015 cropping season. From this point the farmer would require 73% of more land to grow sole crops in order get the same grain yield as that obtained in the intercrop. Likewise, a farmer would require 61% of more land for sole crop to achieve the same biological yield as that obtained in intercropping. With fertilizer application, the highest value of LER for grain yield was 1.68, recorded in 40 kg of K indicating that a farmer would need 68 % of more land to grow sole crops in order to achieve the same grain yield as obtained from intercropping.

For biological yield, the highest LER was 1.64 recorded in plots treated with 26 kg of P with wider spacing of intercrop for the 2016 cropping season. This indicated that there was yield advantage of 64% in intercropping over sole crop. Therefore, a farmer would require 64% of more land for sole crops to achieve the yield obtained in the intercropping. It was also noted that Rhizobia inoculation produced higher LER of 1.61 in wider spacing of intercropping over un-inoculated treatments and narrower spacing of intercrop. Similar to our findings, several studies (Ndakidemi and Dakora, 2007; Hugar and Palled, 2008; Yilmaz *et al*., 2008; Dahmardeh *et al*., 2010; Solanki *et al*., 2011; Amanullah *et al*., 2016) have reported the LER greater than 1.0 indicating the intercropping advantages over sole cropping. From this study, we have noticed reduced values of LER in narrower spacing compared with wider spacing. The reduced LER in narrower spacing of soybean intercropped with maize can be explained by the findings of Ofori and Stern (1987) who reported that light is the determinant of LER of maize and soybean and that LER declines when legume becomes severely shaded. Ijoyah and Jimba (2012) have reported reduction in number of pods of okra intercropped with maize stating the reason being the effects of nutrient and light completion. Furthermore, Santalla *et al*. (2001) reported a reduction of common bean yield in intercropping compared with pure stand due to the effect of shading.

Conclusion

From this study, intercropping maize with soybean was advantageous because all the values of LER were above 1.0. Supplementation of inputs such as *Rhizobium* inoculants and P and K fertilizers significantly ($P<0.05$) increased the LERs over the control. The system was more beneficial in rhizobial inoculated plots which gave the highest LER of 1.73 and 1.61 grain and biological yield compared with un-inoculated plots which gave the lowest LER of 1.31 and 1.39 grain and biological yield respectively. P and K also greatly contributed to the increased LER over the control. Wider spacing of soybean resulted to a greater LER compared with narrower spacing suggesting the use of wider spacing for legume-cereals intercropping.

Therefore, this study suggests that farmers may be advised to intercrop maize with soybean at a recommended spacing, and supplying with the tested inputs above. However, application of P and K fertilizers will depend on the level of these nutrients in respective soil under consideration.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgement

Authors are thankful to the government of Tanzania through Nelson Mandela African Institution of Science and Technology for funding this study.

References

Agegnehu G, Ghizaw A, Sinebo W. 2006. Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. European Journal of Agronomy **25(3),** 202-207. https://doi.org/10.1016/j.eja.2006.05.002.

Amanullah KF, Muhammad H, Jan AU, Ali G. 2016. Land Equivalent Ratio, Growth, Yield and Yield Components Response of Mono-cropped vs. Inter-cropped Common Bean and Maize With and Without Compost Application. Agriculture and Biology Journal of North America, **7(2),** 40-49.

Banik P, Midya A, Sarkar BK, Ghose SS. 2006. Wheat and chickpea intercropping systems in an additive series experiment: advantages and weed smothering. European Journal of Agronomy **24(4),** 325-332. https://doi.org/10.1016/j.eja.2005.10.010.

Beets WC. 1994. Multiple cropping of maize and soybean under a high level of crop management. Netherlands Journal of Agricultural Science **25,** 95-102.

Brintha I, Seran TH. 2009. Effect of paired row planting of raddish (*Raphanus sativus* L.) intercropped with vegetable amaranths (*Amaranths tricolor* L.) on yield components in sandy regosol. The Journal of Agricultural Sciences **4(1),** 19-28.

Dahmardeh M, Ghanbari A, Syahsar BA, Ramrodi M. 2010. The role of intercropping maize (*Zea mays* L) and cowpea (*Vigna unguiculata* L) on yield and soil chemical properties. African Journal of Agricultural Research **5(8),** 631-636.

Dariush M, Ahad M, Meysam O. 2006. Assessing the Land Equivalent Ratio (LER) of two corn [*Zea mays* L.] varieties intercropping at various nitrogen levels in Karaj, Iran. Journal of Central European Agriculture **7(2),** 359-364.

Esmaeili A, Sadeghpour A, Hosseini SMB, Jahanzad E, Chaichi MR, Hashemi M. 2011. Evaluation of seed yield and competition indices for intercropped barley (*Hordeum vulgare*) and annual medic (*Medicago scutellata*). International Journal of Plant Production **5(4),** 395-404.

Ghaffarzadeh M, Prechac FG, Gruse RM, 1994. Grain yield response on corn, soybean and out grown in a strip intercropping system. American Journal of Alternative Agriculture **9(4),** 171–177. https://doi. org/10.1017/S0889189300005932.

Ghosh PK, 2004. Growth, yield, competition and economics of groundnut/cereal fodder intercropping in the semi-arid tropics of India. Field Crop Research **88,** 227-237. https://doi.org/10.1016/j.fcr.2004.01.015.

Giller KE, Wilson KJ. 1991. Nitrogen Fixation and Tropical Cropping Systems. CAB International, Wallingford P. 10-120.

Gliessman SR. 2007. Agroecology: The Ecology of Sustainable Food Systems, 2nd Edn. CRC Press, Taylor and Francis Group. https://doi.org/10.1016/j.fcr. 2004.09.002.

Hugar HY, Palled YB. 2008. Studies on maize-vegetable intercropping systems. Karnataka Journal of Agricultural Sciences **21(2),** 162-164.

Jabbar A, Ahmad R, Bhatti IH, Virk ZA, Wasi-u-Din, Khan MM. 2009. Assessment of yield advantages, competitiveness and economic benefits of diversified direct-seeded upland rice-based intercropping systems under strip geometry of planting. Pakistan Journal of Agricultural Sciences **46(2),** 96-101.

Knudsen MT, Hauggaard-Nielsen H, Joernsgaard B, Jensen ES. 2004. Comparison of interspecific competition and N use in pea–barley, faba bean–barley and lupin–barley intercrops grown at two temperate locations. The Journal of Agricultural Science **142(06),** 617-627. https://doi. org/10.1017/S0021859604004745.

Laster ML, Furr RE. 1972. Heliothis populations in cotton-sesame interplantings. Journal of Economic Entomology **65(5),** 1524-1525. https://doi.org/10. 1093/jee/65.5.1524.

Maingi MJ, Shisanya AC, Gitonga MN, Hornetz B. 2001. Nitrogen fixation by common bean (*Phaseolus vulgaris* L.) in pure and mixed stands in semi arid South east Kenya. European Journal of Agronomy **14,** 1-12. https://doi.org/10.1016/S1161-0301(00)00080-0.

Matusso JMM, Mugwe JN, Mucheru-Muna M. 2012. Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of sub-Saharan Africa Research Application Summary. Third RUFORUM Biennial Meeting 24-28 September 2012, Entebbe, Uganda.

Mc Gilchrist CA, Trenbath BR. 1971. A revised analysis of plant competition experiments. Biometrics **27,** 659-671. https://doi.org/10.2307/2528603.

Mead R, Willey RW. 1980. The concept of a land equivalent ratio and advantages in yields for intercropping. Experimental Agriculture **16(3),** 217-228. https://doi.org/10.1017/S0014479700010978.

Mohammed SAA. 2011. Assessing the Land Equivalent Ratio (LER) of Two Leguminous Pastures (CLITORIA and SIRATRO) Intercropping at Various Cultural Practices and Fencing at ZALINGEI–Western Darfur State-Sudan. ARPN Journal of Science and Technology **2(11),** 1074-1080.

Ndakidemi PA, Dakora FD. 2007. Yield components of nodulated cowpea (*Vigna unguiculata*) and maize (*Zea mays*) plants grown with exogenous P in different cropping systems. Australian Journal of Experimental Agriculture **47(5),** 583-589. https://doi.org/10.1071/EA05274.

Nyoki D, Ndakidemi PA. 2016. Intercropping System, Rhizobia Inoculation, Phosphorus and Potassium Fertilization: A Strategy of Soil Replenishment for Improved Crop Yield. International Journal of Current Microbiology and Applied Sciences **5(10),** 504-522. https://doi.org/ 10.20546/ijcmas.2016.510.056.

Ofori CF, Stern WR. 1987. Cereal legume intercropping systems. Advances in Agronomy **41,** 41-90. https://doi.org/10.1016/S0065-2113(08)60802-0.

Sanchez PA. 1976. Properties and management of soils in the tropics. Wiley, New York. P. 478-532.

Smith HA, Mc Sorley R. 2000. Intercropping and pest management: A review of major concepts. American Entomologist **46(3),** 154-161. https:/ /doi.org/10.1093/ae/46.3.154.

Solanki NS, Singh D, Sumeriya HK. 2011. Resources utilization in Maize (*Zea mays*)-based intercropping system under rainfed condition. Indian Journal of Agricultural Sciences **81(6),** 511-515.

Steel RGD, Torrie JH. 1980. Principles and Procedures of Statistics: A Biometrical Approach," 2nd Edition, McGraw-Hill Kogakusha, New York.

Tsubo M, Walker S, Ogindo HO. 2005. A simulation model of cereal–legume intercropping systems for semi-arid regions: I. Model development. Field Crops Research **93(1),** 10-22. https://doi.org/ 10.1016/j.fcr.2004.09.003

Willey RW, Rao MR. 1980. A competitive ratio for quantifying competition between intercrops. Experimental Agriculture **16 (2),** 117-125. https://doi.org/10.1017/S0014479700010802.

Yilmaz S, Atak M, Erayman M. 2008. Identification of advantages of maize-legume intercropping over solitary cropping through competition indices in the east Mediterranean region. Turkish Journal of Agriculture and Forestry **32(2),** 111-119.