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Impact of associated intercrops on growth and yield of maize (*Zea mays* L) in major seasons of south Asia

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Abstract

Mixed cropping is a feature of smallholder tropical farming systems, and maize (*Zea mays* L) is the most common highland cereal planted in these systems in Asia, under rainfed conditions. A field study thus determined the effect of intercropping maize with four popular food crops, over two major seasons of tropical Asia. The bean (*Phaseolus* spp.) intercrop had no significant impact on growth and yields of maize, while cassava (*Manihot esculenta*) had the most significant adverse effect. The impact of tomato (*Lycospersicon esculentum*) and sweet potato (*Ipomoea batatas*) on maize was in-between those of beans and cassava. The bean, tomato and sweet potato – maize intercrops have LER values greater than unity, while that of cassava maize was lower than 1. Optimizing maize production and resource use in smallholder systems through mixed or intercropping thus requires the selection of suitable crop species.

Keywords: maize, intercropping, major seasons, growth, yields, Asia

Introduction

The production of more food for the growing populations in the coming decades, while combating poverty and hunger at present, is a significant challenge to the developing nations. Thus intercropping principal food crops (eg. cereals) to intensify resource use is considered a key factor in meeting this challenge, in technologies such as evergreen agriculture which is considered a robust approach to sustainable food security in the developing world (Garrity et al, 2010).

Smallholder farms in the tropics, which produce over 60% of the food resources of the developing nations, intercrop cereals with a multitude of crops, and including legumes in these systems is most common and researched due to the synergistic effects, with the objective of diversifying food production and household cash incomes (Rao and Mathuva, 2000; Kimaro et al, 2009). Thus, as the most important highland cereal in Asia is maize (*Zea mays* L) (Timsina et al, 2010), it is often intercropped with legumes to enhance resource use and sustainability of tropical smallholder cropping systems (Tsubo et al, 2005; Witcombe et al, 2008).

Vegetable and tuber crops such as sweet potato (*Ipomoea batatas* L) and cassava (*Manihot esculenta* L Crantz) play a significant role in smallholder farming systems of tropical Asia (Arsanti and Bohme, 2008; Bradshaw 2010). Thus they are intercropped with maize with mixed results (eg. Ossom, 2010; Daellenbach et al, 2005) principally in Africa, with no comparative studies in Asia. The success of these maize and vegetable or tuber crop systems depend on the compatibility of growth forms of the species, their interactions, and resource use and management strategies. However, studies do not present the performance of maize when intercropped with different vegetables or tuber crops on a comparative basis. Thus it was hypothesized that intercropping maize with different food crops will enhance overall productivity of smallholder cropping systems. On this basis, a field study was carried out over two major (wet) seasons of tropical Asia to assess the impact of intercropping four different tropical food crops on the growth and yield of maize and the overall productivity of the system.

Materials and Methods

The field experiment was carried out at the research unit of the Faculty of Agriculture, University of Peradeniya, Sri Lanka, located in the intermediate zone of Sri Lanka (8.0°N, 81°E, 420 m asl) in the (DRY) major (WET) seasons of 2005/6 and 2006/7 (October - March) that correspond to the Northeast monsoons The soil of the site was an Ultisol (Rhododult), with the following characteristics: Texture –Sandy loam, with a pH (1:2.5 H_2O) 6.35 ± 0.41; Total N, Available P and K levels of 45 ± 0.36, 4.42 ± 0.12 and 9.8 ± 0.72 mg/g soil, respectively. CEC of 22.18 ± 2.11 m eq/100 g soil, Organic Matter content of 4.41 ± 0.09 g/kg and a Water Holding Capacity of 18.22.% ± 0.19%.

The climates of the two seasons (2004/5 and 2005/6) were characterized by 1,057 and 1,199 mm of rainfall, received between the periods October – February of each season. The mean daily temperature of both seasons was 29.5°C ± 2.5°C, with a humidity of 84.7% ± 5.0%, and a mean daily evaporation rate

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of 3.11 mm ± 0.12 per day. Thus the crops had sufficient rainfall for growth and supplementary irrigation was not required.

The species selected were maize (*Zea mays* L, var Ruwan) as the main crop and Phaseolus beans (*Phaseolus vulgaris* L, variety Wade), sweet potato (*Ipomoea batatas,* variety Wariyapola red), tomato (*Lycospersicon esculentum*, var Thilina) and cassava (*Manihot esculentum* L Crantz, var MU51) as intercrops.

At the beginning of the seasons (early October of two years) the sites were prepared by mechanical tillage and plots of 4 x 6 m prepared manually. After 14 days, seeds of maize were planted at a spacing of 60 x 30 cm to accommodate 55,000 plants her ha in all plots. Soon after planting maize, the intercrops were established as follows:

Beans – Uniform seeds were planted at a spacing of 20 x 10 cm to accommodate two rows between maize rows;

Sweet potato – Uniform cuttings of 20 cm length were planted at a spacing of 40 cm between plants in a single row between the maize rows;

Tomato – 25 day old uniform seedlings were planted at a spacing of 30 cm between plants in a single row between the maize rows;

Cassava – Uniform cuttings of 30 cm were planted at a spacing of 80 cm between plants in a single row between the maize rows

In addition monocultures of the intercrops were also planted in plots, at the same spacing, used in the intercrops, with the respective species replacing maize. Thus the experiment conducted within a Randomized Block design with four replicated had 5 monoculture and 4 intercrop treatments, located on different sites to avoid carry over effects.

The fertilizers applied to all plots irrespective of being mixtures or monoculture was equivalent to 20 Kg N, 45 Kg P and 30 Kg K per ha at planting and 20 Kg N and 20 kg K per ha three weeks after plating the maize. Weeding was carried out manually on two occasions to maintain weed free plots. There were no serious pests and diseases in both species.

The data obtained in both seasons were as follows: at 15, 30 and 45 days after planting, three maize plants per plot were carefully harvested, roots washed, oven dried at 80°C for 48 hrs, and dry weights determined to calculate the Relative Growth Rate (RGR).

$$\text{RGR} = \frac{\ln(\text{W2}) - \ln(\text{W1})}{T2 - T1}$$

where W1 and W2 are plant dry weights at times T1 and T2 respectively (Hunt, 1990). The RGR was calculated to determine the increments in plant growth over time as affected by the adopted treatments.

The RGR values of the three time intervals were pooled and mean values developed for the vegetative phase. The days to 50% of maize plants to produce silk and for anthesis were noted in each plot and Anthesis – Silking Interval (ASI) determined. At silking, leaf areas of four plants were determined using a Li Cor 3000 series leaf area meter.

At crop maturity, numbers of ears per maize plants were counted on 10 plants selected randomly. The number of kernels per ear was counted on 10 ears per treatment and the seed yield of 25 plants was determined in maize to obtain yields per ha (corrected to 15% moisture content – wet weight basis), and the shoot biomass dried at 80°C for 48 hours to determine Harvest Index (HI) as follows:

HI = Economic yield/Biological yield (Ghosh et al, 2006)

The HI was determined to evaluate the impact of the intercrops on the yields of maize in relation to the total biomass.

At maturity of the intercrops, the fresh weights of bean pods, fresh weights of tomato fruits and tuber yields of sweet potato and cassava were determined on 20 plants per plot and yields per ha deteremined. Thereafter, yield data of maize and the respective yields of the associated species in sole and intercropped plots were used to determine the Land Equivalent ratio (LER) as follows:

LER = (Yab/Yaa) + (Yba/Ybb) (Ghosh et al, 2006)

where Yaa and Ybb are yields of sole crops a and b; Yab and Yba are yields of the respective intercrops. The calculation of the LER enabled the determination of productivity of the different intercropping systems when compared to the respective monocultures. Hence, values of LER greater than 1 are considered advantageous intercrop systems (Ghosh et al, 2006).

The data of the two major seasons were pooled due to similarities in the responses in relation to the adopted treatments, and tested for normality prior to conducting an Analysis of Variance (ANOVA) using the mixed model procedure in the Statistical Analysis Systems package (SAS, 1990), and LSD values (p= 0.05) were used to determine the significance of observed differences between treatments.

Results and Discussion

Intercropping had no significant impact on the establishment of maize (Table 1), due to the slower development of most canopies of these crops when compared to the cereal. This clearly indicated that planting these elected species with maize at the same time has no effect on the cereal, thus ensuring the procurement of the required plant populations, which can be a problem in intercropping systems on smallholder farming systems as shown with cassava in Africa (Olasantan and Bello, 2004). In contrast, RGR of maize was significantly reduced by the intercrops, especially with the tall statured cassava, with its larger canopy. The impact of tomato and sweet was lower, with beans not having any detrimental effect on rates of dry matter accumulation of cereals (Table 1). The growth periods of both tomato

Table 1 - Impact of intercropping on establishment and vegetative growth of maize (mean of two major seasons).

Intercrop	Establishment (%)	RGR# $g.g^{-1}.day^{-1}$	LAI at silking	Days to silking	ASI days
Beans	89	0.121	3.6	56	3.2
Sweet potato	84	0.114	3.3	55	3.7
Tomato	85	0.101	3.3	56	3.7
Cassava	85	0.106	2.9	61	4.9
Maize sole crop	86	0.124	3.8	54	3.1
LSD (p=0.05)	3.29	0.018	0.12	3.2	0.33

#RGR is mean value between Leaf Developments Stage 2 – Silking, based on dry weights taken at 15 day intervals

and sweet potato are similar to that of maize (3½ -4 months) and beans have a 45-50 day duration, while cassava continues to remain in the field for a total of 8½-9 months. The longer duration of cassava seems to have a greater adverse effect on dry matter accumulation, in contrast to those with similar or shorter periods of growth, a phenomenon not identified earlier. The lowest impact on RG of maize was with beans, which could be suet to the shorter growth period, which is completed before silking of the cereal. This also agrees with the results of Dawo et al (2009), under temperate conditions of England. The overlap of the complete cropping cycles in maize and sweet potato and tomato seem to have lower competitive effects than with cassava, and this needs verification as most studies (eg. Dapaah et al, 2003) evaluate yields.

The LAI of maize (Table 1) as affected by the intercrops follow that of RG, thus developing a significant positive correlation (r=0.76*) between the two parameters. Intercropping with beans had the lowest impact on the LAI of maize, followed by that of sweet potato and tomato. This is due to the short stature of these species when compared to maize. As expected the greatest reduction in maize LAI was when intercropped with cassava, the tallest among the selected species. Thus the lower LAI due to intercropping could reduce the photosynthetic capacity of maize, resulting in lower dry matter accumulation as shown by the RGR. This reduction in growth rates leads to the delaying of silking (Table 1). The impact of intercropping maize with beans, sweet potato and tomatoes was not significant in terms of days to silking, although there was a marginal delay when compared to the monocrop. However the interval between silking and anthesis (ASI) was extended due to to intercropping (Table 1) which again illustrated the impact of the stress factors due to competition, which h delays anthesis (Edmeades et al, 2000). The negative relationship between RGR and ASI (as ASI increased with reduction of RGR) was again significant (r = 0.69*). This indicated that the adverse impact of short duration crops (beans) or short statured crops (tomato and sweet potato) on the vegetative growth of maize is not as great as that from cassava, which a taller and long duration crop is. Such comparative studies have not been reported earlier.

Intercropping with different species had no significant impact on ears per plant of maize (Table 2), as this is generally a species characteristic, which is not affected my management factors such as fertilizers and intercropping (Sharifi and Taghizadeh, 2009; Singh et al, 2000). In contrast, grain filling as depicted by kernels per ear, is affected by intercropping (Table 2), as competition affects yield components of maize (Singh et al, 2000; Dawo et al 2009). Intercropping with beans reduced kernels per ear by 7%, while the reduction due to sweet potato and tomato was in the range of 10-11%. The most significant reduction in this parameter was due to the cassava intercrop (25%). This is attributed to the reduction in dry matter accumulation and to the retardation of the photosynthetic capacity, due to the significant positive correlation between kernels per cod and RGR (r =0.42*) and LAI (r= 0.59*). This also indicates the greater impact of LAI on kernel development, as they provide the carbohydrates through photosynthesis (Alvin et al, 2010).

Smallholder farmers grow different species for food and sale, and yields are the most essential factors determining crop selections (Smithson and Giller, 2002). As expected, maize monocultures yielded the most (Table 2) and intercropping with beans, the short statured short term crop reduced seed yields marginally (2%). In contrast, intercropping single rows of sweet potato or tomato, which have a similar cropping period as maize reduced yields by 17% and 22% respectively, suggesting that tomato have a greater adverse impact on maize yields than sweet potato, which could be attributed to the below ground development of tubers in sweet potato, thus utilizing different resources. The most significant impact of intercropping on seed yields of maize was with cassava, where the yield reduction was some 49%, when compared to the maize monocrop. This clearly implied the adverse effect of the tall long duration crop on maize. The correlations between seed yields with and RGR, LAI and kernels per ear were also all positive and significant (r = 0.49*; r = 0.74*; r = 0.66*, respectively), thus indicating the highest impact of leaf area on grain yields in this study, as stated by Long et al (2006) for grain crops. Thus harvest indices (HI)

Table 2 - Yield components and seed yields of maize as affected by intercrops (mean of 2 major seasons).

Intercrop	Ears.plant^{-1}	Kernels.ear^{-1}	Seed yield. Mg. ha^{-1}	HI
Beans	1.24	321	4.04	0.41
Sweet potato	1.20	311	3.42	0.38
Tomato	1.21	306	3.23	0.37
Cassava	1.04	261	2.10	0.32
Maize sole crop	1.30	347	4.15	0.41
LSD (p=0.05)	0.24	12.5	0.28	0.01

(Table 2) were also affected by intercropping, where cassava reduced the economic yield to the greatest extent. Thus for optimal yields of maize, the best intercrop is beans, the short statured early maturing species, which seem to offer the least completion to the cereal crop. Intercropping with cassava has the greatest impact on growth and yields, and the effect of tomato and sweet potato was lower, making the latter partially acceptable.

The impact of intercropping on the yields of the associated crops and Land Equivalent Ratios (LER) (Table 3) illustrate the overall performance of the cropping systems. The yields of beans, sweet potato, tomato and cassava were reduced by 31%, 40%, 38% and 53% respectively due to intercropping with maize. This also showed the greater competition between the taller and longer duration crop cassava and maize, when compared to that of tomato and sweet potato which have similar growth durations. The greater biomass accumulation of cassava could be considered a causal factor for this phenomenon, when compared to yields of the other crops. The lowest impact of maize was on beans, again due to the short stature, early harvest and possibly due to synergistic effect of the legume on maize. However the LER values indicate that with the exception of the maize – cassava intercrop system, all others have a greater resource use and complementarity when compared to their respective monocultures as these values exceed unity as shown by maize - legume (Gao et al, 2010) and maize - sweet potato (Ossom, 2010) systems in Asia and Africa. Thus, this study which compared the productivity of maize, the most popular highland cereal in Asia, when intercropped with three popular tropical crops under field conditions, illustrates that, while yields of maize and the associated crops are reduced to some extent with species such as tomato and sweet potato, the lowest adverse effect is with beans, while the least productive is with cassava. However the LER values highlight the benefits of the maize system with beans, tomato and sweet potato, which will be useful for crop selections in mixed smallholder farming systems, which need to optimize resource use while producing a diverse range of species for consumption and possible sale. In contrast, intercropping maize with cassava does not seem a suitable option, both in terms of growth of maize, yields of both species and resource use, as depicted by the LER values.

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Table 3 - Yields of intercrops and LER of the cropping systems as affected by maize intercropping (mean of 2 major seasons)

Crop	Cropping system	Yield Mg.ha^{-1}	LER
Beans (pods)	Intercrop	5.84 ± 0.20	1.43[a]
	Monocrop	8.56 ± 0.09	
Sweet potato	Intercrop	12.55 ± 1.30	1.36[b]
	Monocrop	20.41 ± 2.04	
Tomato	Intercrop	3.85 ± 0.41	1.38[b]
	Monocrop	6.26 ± 0.19	
Cassava	Intercrop	15.41 ± 2.13	0.98[c]
	Monocrop	32.60 ± 3.22	

± indicates SE of means (n=6);
LER values followed by the same letter are not significantly different (p=0.05)

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