Maize and Pea Yield and Yield Components of Morphologically Contrasting Maize and Pea Cultivars in Sole and Intercrops in Temperate Conditions

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Resumé

Kanton, R. A. L. & Dennett, M. D. *Le Rendement des Maïs et des Pois et les Composants des Rendements de leurs Cultures Morphologiquement Contrastées dans les Conditions Tempérées au Niveau de la Culture Unique et Culture Intercalaire.* Les expériments du terrain étaient entameś lors de la saison 2000 et 2007. Le lieu d' expériments était à l'université de Reading, précisement au terrain de l' école phytotechnologie de l'université de Reading à shinfield. L'objectif était à déterminer les effets sur le rendement morphologiquement opposés. Les variétés du maïs étaient "sophy" et "nancy" avec les caractéristiques hébreuses planophilies et les caractéristiques hébreuses érigées respectivement. Dans le cas des pois, les variétés étaient "maro" et "princess" avec les caractéristiques hébreuses normales et démi-normales respectivement. Dans tous les deux ans, l'intercalaire des pois et des maïs ont abouti à un rendement réduit dans le cas du maïs par repport à la cultivation unique. Pourtant la réduction en rendement était variable entre les pois et les années. En 2000, l'intercalaire du maïs et "maro" a abouti à 58% réduction en rendement et 27% dans le cas de "princess". Pourtant en 2001, l' intercalaire du maïs avec "princess" a réduit le rendement par 66% par rapport à 20% pour "maro". L'intercalaire du maïs en 2000 a indiqué un rendement plus élevé que la culture unique. En 2001, l'intercalaire du maïs et "maro" avait indiqué un rendement plus éléve. En 2000 l'intercalaire des "maro" et "Nanci" avait indiqué le plus élevé rendement alors qu'en 2001 l'intercalaire des pois et "Nanci" avait indiqué un rendement comparable à pois unique. En 2000, "maro" avait indiqué un rendement plus élevé que "princess" dans tous les deux cas c-à-d la culture unique et la culture intercalaire. Pourtant en 2001 le rendement du "princess" était plus élevé que celui du "maro". Dans tous les deux ans l'intercailaire des pois avait régulièrement plus de semences m^{-2} que les pois unique. Le poids moyen de la semence était plus grand dans le cas des pois intercalaires en 2000 alors qu'en 2001 le pois unique avait un poids moyen de la semence plus grand que le pois intercalairé. Le pois intercalairé en 2000 avait une plus grande récolte que le pois unique alors qu' en 2001 le pois unique avait une plus grande récolte que le pois intercalairé. Le rendement du maïs intercalairé était régulièrement petit par rapport à leur éguivalent c-à-d culture unique, mais la réduction était plus grande avec le "maro" que le "princess".

Mots clés: Culture intercalaire, morphologie de plante, maïs, pois, rendement.

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Abstract

Field experiments were conducted in 2000 and 2001 cropping seasons at the Field Unit of the School of Plant Sciences of the University of Reading at Shinfield to determine the effects on yield of intercropping morphologically contrasting maize and pea cultivars. The maize varieties were 'Sophy' with a planophile leaf habit and 'Nancis' with an erect leaf habit. The two pea varieties were 'Maro' with a normal leaf habit and 'Princess' with a semi-leafless habit. In both years pea intercropped with maize resulted in smaller maize yields compared to their sole crop counterparts. However the reduction in yield was variable between pea cultivars and years. In 2000 maize intercropped with 'Maro' resulted in 58% yield reduction and 27% for 'Princess'. However in 2001 intercropping maize with 'Princess' reduced yield by 66% compared with 30% for 'Maro'. Intercropped maize in 2000 had slightly greater harvest index than sole maize. In 2001 maize intercropped with 'Maro' had the greater harvest index. In 2000 'Maro' intercropped with 'Nancis' had the largest yield whilst in 2001 intercropping pea with 'Nancis' had comparable yield with sole pea. 'Maro' in both sole and intercrops in 2000 had greater yield than 'Princess' whilst in 2001 'Princess' in both cropping systems had greater yield than 'Maro' In both years intercropped pea had consistently more seeds m^{-2} than sole pea. Mean pea seed weight was greater for intercropped pea in 2000 whilst in 2001 sole pea had greater mean seed weight than intercropped pea. Intercropped pea in 2000 had greater harvest index than sole pea whilst in 2001 sole pea had greater harvest index than intercropped pea. Intercropped maize yields were consistently smaller compared to their sole cropped counterparts but the reduction was greater with normal leaved pea 'Maro' than the semi-leafless pea 'Princess'.

Keywords: Intercropping, plant morphology, maize, pea, yield.

Introduction

Intercropping will probably be an essential part of future agriculture because it uses environmental and other resources more efficiently than does sole cropping (Innis, 1997). Oljaca *et al.* (2000) observed that there is mounting interest in intercropping in temperate climates because of its improved crop protection and increased productivity. Genotypes that minimize competition and maximize complementarity are desirable for intercropping (Rao and Mittra, 1990). Thorsted *et al.* (2002) emphasized the importance of understanding intercropping competition in order to improve cereal/legume yields. The influence of plant type on competitiveness has been reported in maize-cowpeas (Wien and Nangju, 1976; Wahua *et al.* (1981), maize-beans (Francis *et al.*, 1982). Tarhalkar and Rao (1975), in evaluating a number of crop combinations, ideotypes and planting patterns recommended that dwarf erect types of sorghum, castor bean and pigeon pea were most suitable for intercropping.

In an experiment designed to determine the effect of morphologically different types of maize with cowpea on growth

attributes of cowpea, Wahua *et al.* (1981) demonstrated that the reduction caused by intercropping on grain yield and it's attributes depended greatly on the associated maize cultivars.

The objectives of the study were to compare: (1) the effects of morphologically contrasting maize and pea cultivars on the yield and yield components of maize and pea in sole cropping and intercropping and (2) the advantages of intercropping to sole cropping.

Materials and methods

Two field experiments were conducted at the Field Unit of the School of Plant Sciences, at Shinfield (Latitude 51° 25' N, Longitude 0° 56'W and 40 m a s l) from June to October in 2000 and May to October in 2001. In 2000 the experiment followed fallow, which had for the previous six years been cropped, to wheat. In 2001 the experiment was established on a field that had been under natural pasture for several years. The total experimental area was 3,760 m (94 m x 40 m) in both years. The soil was a clay loam overlying river terrace gravel, belonging to Hurst Series (Jarvis, 1968). The top 30 cm of the field planted to the first year experiment was sandy whilst that of the second year had more gravel and stones. In both fields the clay content increased gradually with depth.

The experimental material used in all experiments comprised of two morphologically contrasting cultivars of maize and of peas. The maize cultivars investigated were Nancis and Sophy and the peas were Maro and Princess. Maize cultivar Nancis has a below average dry matter yields of very high dry matter content. It has very early cob maturity and belongs to maturity class 7 (NIAB, 1999b). It has an erect leaf habit, good early vigour and matures rapidly. Maize cultivar Sophy has high dry matter yields of high dry matter content. Sophy is tall at harvest, but with good standing ability and is from maturity class 10 (NIAB, 1999b). It has the traditional droopy leaf habit.

Pea cultivar Maro is a normal-leaved, marrowfat variety, the preferred variety for the canning industry and is suitable for all other human consumption end uses. In common with other marrowfat varieties, it is late maturing with poor standing ability and ease of combining. It belongs to NIAB (1999a) recommended variety category S. Pea cultivar Princess is a moderately tall-strawed, semi-leafless, marrowfat variety possessing good standing ability and ease of combining. It is usually preferred for canning as whole peas. It is rather susceptible to downy mildew and therefore seed treatment would usually be required. It belongs to NIAB (1999a) recommended variety category S. The cultivars can be summarised as 'Nancis' maize; erect growth habit, 'Sophy' maize; droopy growth habit, 'Maro' pea; normal leaved, 'Princess' pea, semi-leafless.

Weather conditions during the experimental period in both years

Total rainfall during the growing season was 234.2 mm in 2000 compared to 225.5 mm in 2001. In 2000 there were 50 rainy days compared to only 43 days in 2001. The seasonal mean minimum temperature in 2000 was 11.2 ^{0}C compared to 10.8 ^{0}C in 2001. In 2000 the total seasonal mean radiation was 13.1 MJ m^{-2} compared to 15.9 MJ m^{-2} in 2001.

In 2000 the field was ploughed in February and in May cultivated, ring-rolled and leveled. NPK compound fertilizer 15:15:15` was broadcast by hand at the rate of 40 kg N 40 kg P_2O_5 and 40 kg K_2O ha^{-1}, and no fertilizer was applied in 2001. Peas were drilled using a Winter Steiger Precision Seed Driller on June 6 2000 and maize was hand sowed on June 7 and 8. In 2001 peas were drilled on May 24 whilst maize was hand sowed on May 25 and 26. Peas were sowed at a density of 71 plants m^{-2} giving a plant population density of 710,000 plants ha^{-1} and maize at a density of 6 plants m^{-2}. In the intercrops, maize rows were spaced at 0.75 m apart with a within row spacing of 0.30 m. Each maize row was alternated with 5 pea row at 0.12 m apart with a within row spacing of about 0.07 m. The same maize and peas densities were adopted for their respective sole crops thus giving an additive design (Snaydon, 1991). Weeds were controlled by hand weeding on 14 and 28 d after sowing.

The field experiments in both years were laid out in a randomised complete block design with 3 replications. The experimental plots were 7m x 10 m (70 m^2) with a distance between replications and plots of about 5.0 m. The experimental treatments comprised of all possible combinations of the 2 maize and 2 peas cultivars and their respective sole crops. This gave a total of 8 treatments per replicate and 24 plots for the entire experiment.

Maize and peas were harvested at maturity by uprooting when over 80% of leaves plant^{-1} of more than 75% of the plants had turned yellow to brown. Samples were taken from a 1m^2 area for yield determination. In 2000 peas were harvested on August 30 (81 DAS) and in 2001 on August 20 (87 DAS). In both years 'Princess' pea matured slightly earlier than 'Maro' pea but both cultivars were harvested at the same time. For maize in 2000 harvesting was done on October 12 (127 DAS) and in 2001 on October 2 (128 DAS). For maize, number of cobs plant^{-1}, kernel rows cob^{-1}, kernels row^{-1}, number of kernels m^{-2}, number and weight of shrivelled seed and single kernel weight were recorded. Maize seed yield was also determined excluding wrinkled seed. For peas the following yield components were determined; number of pods plant^{-1}, seeds pod^{-1}, seed weight pod^{-1}, pod and seed number m^{-2}, number and weight of shrivelled seed and single seed weight. Maize kernel and pea seed yields (g m^{-2}) are considered as follows: (a) the product of harvest index and total dry

matter, and (b) the product of kernel (seed) number m^{-2} and kernel (seed) weight(g).

The Statistical Analytical Systems Programme (SAS 2001) was used to organise and analyse data, using either the PROC ANOVA or PROC GLM procedures.

Results

Maize kernel yield m^{-2}

Maize yields were affected (p <0.001) by pea cultivar (Table 1). Sole 'Nancis' maize produced the largest kernel yield m^{-2} with 'Sophy' maize intercropped with 'Maro' pea the least. Intercropping peas with maize resulted in a significant reduction in kernel yield m^{-2} but the reduction was largest when both maize cultivars were intercropped with 'Maro' pea (58%) compared to 'Princess' pea (27%). 'Nancis' maize had greater kernel yield m^{-2} in all treatments with a mean 13% greater than 'Sophy' maize. 'Nancis' maize-'Princess' pea (564 g m^{-2}) had the largest intercrop yield (Table 1). In 2001 maize yield was affected (p <0.001) by maize and pea cultivars (Table 1). 'Nancis' maize in sole crop recorded the largest and significantly greater kernel yield m^{-2} compared to the remaining treatments. 'Sophy' maize intercropped with 'Princess' pea produced significantly smaller kernel yield m^{-2} compared to their other intercrop counterparts (Table 1). Intercropping with 'Princess' pea caused the greatest reduction in kernel yield m^{-2} (66%) compared to 'Maro' pea (30%). 'Nancis' maize had a greater mean yield (39%) compared to 'Sophy' maize. In both seasons 'Nancis' maize consistently produced the largest yield m^{-2} compared to the remaining treatments. Whilst intercropping maize with 'Maro' pea in 2000 resulted in the largest yield reduction, intercropping with 'Princess' pea in 2001 resulted in the greatest reduction. 'Nancis' maize in both sole and intercrops produced greater kernel yields compared to their 'Sophy' maize counterparts. Kernel yield m^{-2} for both sole and intercrops were greater in 2001 compared to 2000 except for 'Sophy' maize intercropped with 'Princess' pea which resulted in a mean yield reduction of 35% in 2001 compared to 2000. Comparing 2001 with 2000, sole maize crops, showed an 18% increase, intercrops with Maro 44% and intercrops with 'Princess' pea an 11% decrease.

Maize dry matter

There was a year x variety interaction for maize dry matter (p <0.05). In 2000 sole 'Nancis' maize had the largest dry matter followed by sole 'Sophy' maize, with 'Nancis' maize intercropped with 'Maro' pea recording the least dry matter. 'Nancis' maize intercropped with 'Princess' pea accumulated the largest dry matter amongst the intercrops (Table 1).

In 2001 'Nancis' maize sole cropped recorded the greatest dry matter followed by sole 'Sophy' maize with

Table 1. Maize kernel yield and yield components of morphologically and physiologically contrasting maize-pea cultivars in intercrops and sole crops.

	2000				*2001*			
Kernel yield (g m^{-2})	*Maro*	*Princess*	*Sole*	*Mean*	*Maro*	*Princess*	*Sole*	*Mean*
Nancis	435	546	712	564	643	572	930	715
Sophy	402	492	609	501	557	364	626	516
Mean	418	519	661		600	468	778	
LSD (0.05)	M*P=141	P=100	M=81		M*P=156	P=110	M=90	
Dry matter (g m^{-2})								
Nancis	810	1007	1397	1071	946	855	1342	1048
Sophy	816	927	1186	976	950	596	1134	893
Mean	813	967	1292		948	726	1238	
LSD (0.05)	M*P=204	P=145	M=117		M*P=185	P=130	M=107	
Harvest index								
Nancis	0.55	0.52	0.50	0.52	0.58	0.55	0.59	0.57
Sophy	0.50	0.54	0.46	0.48	0.49	0.53	0.44	0.48
Mean	0.52	0.53	0.48		0.57	0.48	0.52	
LSD (0.05)	M*P=0.1	P=0.07	M=0.06		M*P=0.08	P=0.26	M=0.05	
Cobs per plant								
Nancis	1.0	1.1	1.4	1.2	1.6	1.3	2.0	1.6
Sophy	1.0	1.0	1.0	1.0	1.2	1.0	1.5	1.2
Mean	1.0	1.1	1.2		1.4	1.2	1.8	
LSD (0.05)	M*P=0.48	P=0.34	M=0.28		M*P=0.38	P=0.27	M=0.22	
Kernels m^{-2}								
Nancis	2229	2264	3445	2779	2874	2700	4284	3286
Sophy	2059	2283	2697	2346	2654	1848	2928	2477
Mean	2144	2474	3071		2764	2274	3606	
LSD (0.05)	M*P=580	P=410	M=335		M*P=504	P=356	M=291	
Kernel weight (mg)								
Nancis	203.7	209.3	201.0	204.7	193.3	200.3	200.3	198.0
Sophy	193.3	205.0	213.0	204.0	196.0	174.0	196.7	188.9
Mean	198.5	207.0	207.0		194.7	187.2	198.5	
LSD (0.05)	M*P=34.0	P=19.6	M=24.0		M*P=29.7	P=17.	M=21.0	

'Sophy' maize intercropped with 'Princess' pea recording the least (Table 1). 'Sophy' maize-'Maro' pea recorded the largest intercropped drymatter followed closely by 'Nancis' maize-'Maro' pea whilst 'Sophy' maize intercropped with 'Princess' pea accumulated the least dry matter (Table 1).

In both seasons sole 'Nancis' maize consistently accumulated the largest dry matter followed by sole 'Sophy' maize. 'Nancis' maize in both sole and intercrops in both years accumulated greater dry matter than their 'Sophy' maize counterparts. In 2000 intercropping maize with Maro resulted in decreased dry matter whereas in 2001 maize intercropped with 'Princess' pea caused the greatest depression of intercropped maize dry matter. This depression in intercropped maize dry matter depended upon the competitive ability of pea in any given season.

Maize harvest index

In 2000 maize harvest index was not affected by maize or pea cultivar or their interaction effects. 'Nancis' maize intercropped with 'Maro' pea resulted in the largest harvest index whilst sole 'Sophy' maize recorded the least. Intercropping maize with 'Maro' pea and 'Princess' pea resulted in almost significant mean increase in harvest index of 8% and 6% respectively compared to their sole maize counterparts. 'Nancis' maize in both sole and intercrops produced a greater mean harvest index of 8% over 'Sophy' maize.

Maize harvest index was affected (p <0.05) by pea cultivar. Sole 'Nancis' maize produced the largest harvest index whilst 'Sophy' maize intercropped with 'Maro' pea the least. 'Nancis' maize produced greater harvest index (p <0.05) compared to 'Sophy' maize (Table 1). Similarly 'Nancis' maize intercropped with 'Maro' pea resulted in greater (p <0.05) harvest index compared to sole 'Sophy' maize and the intercrops. 'Nancis' maize intercropped with 'Princess' pea also resulted in a greater harvest index than 'Sophy' maize intercropped with both pea cultivars. 'Sophy' maize intercropped with 'Princess' pea resulted in a smaller (p <0.05) harvest index compared to Sophy intercropped with 'Maro' pea. Maize intercropped with 'Maro' pea achieved a mean increase in harvest index of 19% over maize intercropped with 'Princess' pea and 10 % over sole cropped maize.

In both seasons intercropping maize with 'Maro' pea produced consistently greater harvest index than when maize was intercropped with 'Princess' pea or sole cropped. There was a 10% increase in harvest index in 2001 over 2000 when maize was intercropped with 'Maro' pea and 8% increase for the sole cropped maize, however the harvest index when maize was intercropped with 'Princess' pea in 2001 was 6% less compared to 2001.

Maize cobs plant^{-1}

In 2000 maize cobs plant^{-1} was not affected (p <0.05) by treatment effects. Sole 'Nancis' maize produced the largest number of cobs plant^{-1} compared to the other treatments.

In 2001 number of cobs plant^{-1} was affected (p <0.01) by maize and pea cultivars. 'Nancis' maize produced the most more cobs plant^{-1} compared to the

other treatments (Table 1). Intercropping 'Nancis' maize with 'Maro' pea produced more cobs plant^{-1} (p <0.01) than when 'Sophy' maize was intercropped with both pea cultivars (Table 1). 'Sophy' maize intercropped with 'Princess' pea produced the least number of cobs plant^{-1}.

In both years sole 'Nancis' maize produced significantly greater cobs plant^{-1} compared to the other treatments, whilst 'Sophy' maize intercropped with 'Princess' pea consistently produced the least cobs plant^{-1}. In 2001 both sole and intercrops produced more cobs plant^{-1} compared to 2000. Intercropping maize with 'Maro' pea in 2000 resulted in a greater reduction in cobs plant^{-1} (40%) compared to 'Princess' pea (9%) and for the sole maize more cobs plant^{-1} (50%) were produced in 2001 compared to 2000.

Maize kernels m^{-2}

In 2000 number of maize kernels m^{-2} was affected by maize ($p < 0.05$) and pea cultivars ($p < 0.01$). 'Nancis' maize produced more kernels m^{-2} compared to the rest of the treatments (Table 1). 'Sophy' maize produced more kernels m^{-2} than 'Sophy' maize-'Maro' pea intercropped. The least kernel number m^{-2} was obtained when 'Sophy' maize was intercropped with 'Maro' pea. Intercropping maize with 'Maro' pea resulted in a greater reduction in number of kernels m^{-2} by 43% compared to 'Princess' pea (24%). 'Sophy' maize produced 18% more kernels m^{-2} than 'Nancis' maize.

In 2001 effects of maize and pea cultivars and their interactions were significant on number of maize kernel m^{-2}. Sole 'Nancis' maize produced the largest and intercrop 'Sophy' maize-'Princess' pea the least kernels m^{-2} (Table 1). 'Nancis' maize produced significantly more kernels compared to the other treatments. Maize intercropped with 'Princess' pea caused a greater reduction in kernel m^{-2} (59%) compared to 'Maro' pea (30%). 'Nancis' maize produced more kernel m^{-2} (33%) compared to 'Sophy' maize.

In both seasons 'Nancis' maize produced consistently the largest number of kernels m^{-2}. Intercropping with 'Maro' and sole maize in 2001 resulted in a 29% and 17% increase in number of kernels m^{-2} respectively, whilst intercropping with 'Princess' pea in 2001 resulted in a reduction (9%) in kernels m^{-2}.

Maize single kernel weight (mg)

Maize kernel weight was not affected by treatments in both years. Sole 'Sophy' maize recorded the largest single kernel weight whilst 'Sophy' maize intercropped with 'Maro' pea recorded the least (Table 1). Intercropping maize with 'Princess' pea and sole maize produced kernels that were very similar in weight whilst intercropping with Maro produced kernels that were slightly lighter in weight. 'Nancis' maize

intercropped with 'Princess' pea and sole 'Nancis' maize produced bolder kernels whilst 'Sophy' maize intercropped with 'Princess' pea resulted in lighter kernels (Table 1). In 2001 mean kernel weight for both sole and intercropped maize was considerably less than in 2000, but the greatest reduction was obtained when maize was intercropped with 'Princess' pea (11%) compared to 4% for the sole maize and only 2% when intercropped with 'Maro' pea.

Pea seed yield

Pea yield m^{-2} was not affected (p <0.05) by maize, pea or their interaction effects in 2000. 'Maro' pea intercropped with 'Nancis' maize gave the largest seed yield m^{-2} whilst intercropping 'Princess' pea with 'Nancis' maize gave the least (Table 2). Intercropping peas with maize resulted in comparable seed yield with sole pea. 'Maro' pea in both sole and intercrops produced slightly greater mean seed yield m^{-2} compared to their 'Princess' pea counterparts, but this was not significant.

Pea seed yield was different (p <0.01) between pea cultivars in 2001. Mean seed yield of 'Princess' in both sole and intercropping in 2001 was greater than 'Maro' pea in both sole and intercrops. Sole 'Princess' pea had the largest seed yield and 'Maro' pea intercropped with 'Sophy' maize the least (Table 2). Intercropping 'Maro' pea with maize resulted in greater seed yield than sole pea. However intercropping 'Princess' pea with maize caused a reduction in seed yield but the reduction was greater when intercropped with 'Sophy' maize (17%) than 'Nancis' maize (7%).

In 2000 the intercrops tended to out-yield the sole crops whilst in 2001 intercropping pea with 'Nancis' maize produced comparable seed yield as sole pea. Both intercrops and sole crops had greater yields in 2001 than in 2000. 'Maro' pea in both sole and intercrops out-yielded 'Princess' pea in 2000 whilst in 2001 'Princess' pea, in both intercrops and sole crops, yielded greater than 'Maro' pea.

Pea dry matter

'Maro' pea intercropped with 'Nancis' maize resulted in the largest pea dry matter followed by sole 'Princess' pea with 'Nancis' maize-'Princess' pea recording the least in 2000 (Table 2). Intercropping 'Princess' pea with 'Sophy' maize and sole 'Princess' pea accumulated greater dry matter than when intercropped with 'Nancis' maize.

In 2001 'Princess' pea intercropped with Sophy' maize accumulated the largest dry matter followed by sole 'Princess' pea with 'Maro' pea intercropped with 'Sophy' maize recording the least dry matter (Table 2).

In both seasons pea intercropped with maize accumulated greater or comparable dry matter as sole pea. Whereas in 2000 'Maro' pea in both sole and intercropping recorded the largest dry matter in 2001 'Princess' pea in both

Table 2. Pea seed and yield components as affected by intercropping morphologically and physiologically contrasting maize-pea cultivars (2000-2001).

Yield ($g\ m^{-2}$)	*Nancis*	*Sophy*	*Sole*	*Mean*	*Nancis*	*Sophy*	*Sole*	*Mean*
Maro	243	239	183	222	298	206	293	265
Princess	168	201	213	194	394	361	421	392
Mean	206	220	198		346	283	357	
LSD (0.05)	M*P=86	M=61	P=50		M*P=125	M=88	P=72	
Dry matter ($g\ m^{-2}$)								
Maro	921	741	741	801	533	481	560	525
Princess	621	783	858	754	662	772	738	724
Mean	771	762	800		598	627	649	
LSD (0.05)	M*P=315	M=223	P=183		M*P=231	M=163	P=141	
Harvest index								
Maro	0.42	0.42	0.27	0.37	0.26	0.19	0.27	0.24
Princess	0.29	0.30	0.32	0.30	0.32	0.30	0.32	0.31
Mean	0.35	0.36	0.30		0.29	0.25	0.30	
LSD (0.05)	M*P=0.22	M=0.16	P=0.13		M*P=0.12	M=0.08	P=0.07	
Seeds m^{-2}								
Maro	903	877	820	866	962	675	882	940
Princess	742	914	795	817	1345	1230	1360	1311
Mean	822	895	808		1153	952	1121	
LSD (0.05)	M*P=214	M=151	P=124		M*P=323	M=228	P=186	
Seed weight (mg)								
Maro	258	275	263	265	275	258	300	278
Princess	239	234	223	232	257	269	272	266
Mean	249	255	243		266	264	286	
LSD (0.05)	M*P=34	M=24	P=20		M*P=21	P=15	M=12	

sole and intercrops accumulated the largest dry matter.

Pea harvest index

Harvest index (HI) of pea was not affected (p <0.05) by maize, or pea or their interaction in 2000 (Table 2). Intercropping resulted in greater harvest indices than sole pea but intercropping with 'Sophy' maize resulted in a greater increase in harvest index compared to 'Nancis' maize. 'Maro' maize had a greater mean harvest index than 'Princess' pea sole and intercrops.

Harvest index of pea was affected (p <0.05) by pea cultivar in 2001. 'Princess' pea in sole and intercrops had a greater mean harvest index than 'Maro' pea. Sole 'Princess' pea and 'Nancis' maize-

'Princess' pea intercropped recorded the greatest HI whilst 'Maro' pea intercropped with 'Sophy' maize the least harvest index. 'Princess' pea sole and intercrops achieved significantly greater harvest indices compared to 'Maro' pea intercropped with 'Sophy' maize (Table 2). 'Maro' pea intercropped with 'Sophy' maize resulted in a significantly greater harvest index compared to sole Maro.

Intercropping peas with maize in 2001 resulted in a lower mean harvest index as compared to that obtained in 2000, but the reduction was greater when pea was intercropped with 'Sophy' maize compared to Nancis. 'Maro' pea had a greater harvest index than Princess in 2000, whilst in 2001 'Princess' pea had a greater harvest index than Maro.

Pea seeds m^{-2}

In 2000 pea seed m^{-2} was not affected (p <0.05) by treatments. The largest seed number m^{-2} was obtained when 'Sophy' maize was intercropped with 'Princess' pea with 'Nancis' maize-'Princess' pea intercrop recording the least (Table 2). Peas intercropped with maize produced more seed m^{-2} compared to sole cropped peas, but the greater increment was obtained when pea was intercropped with 'Sophy' maize (11%) than Nancis (2%). 'Maro' pea in both sole and intercrops recorded a mean increase of 6% in seed m^{-2} compared to 'Princess' pea.

In 2001 pea cultivar affected (p <0.001) pea seed number m^{-2}. 'Princess' pea in both sole and intercrops produced significantly greater mean seed m^{-2} than their Maro counterparts. Sole 'Princess' pea recorded the largest seed m^{-2} than Maro intercropped with both maize cultivars. 'Maro' pea intercropped with Sophy' maize produced the least seed m^{-2} compared to the rest of the other treatments (Table 2). Peas intercropped with 'Nancis' maize resulted in a greater mean seed number m^{-2} compared to when intercropped with 'Sophy' maize and sole peas. Similarly sole peas had greater mean seed m^{-2} compared to when peas was intercropped with 'Sophy' maize.

In both seasons intercropping produced similar seed m^{-2} compared to sole peas. Pea produced more seeds in 2001 than 2000 but the increase was greatest when pea was intercropped with 'Nancis' maize (14%) followed by sole peas (39%) and for pea intercropped with 'Sophy' maize (6%).

Pea single seed weight (mg)

In 2000 maize and pea cultivars and their interactions affected pea single seed weight. 'Maro' pea in both sole and intercropping produced significantly larger seed (14%) compared to their 'Princess' pea counterparts. The largest seed weight of pea was obtained by 'Sophy' maize-'Maro' pea with sole 'Princess' pea recording the least. 'Maro' pea intercropped with Sophy produced significantly bolder seed compared to 'Princess' pea intercropped with both

maize cultivars and sole 'Princess' pea (Table 2). Pea intercropped with maize resulted in greater mean seed weight compared to their sole cropped counterparts.

There was a significant year x variety interaction on pea seed weight. Sole 'Maro' pea obtained the largest mean seed weight whilst Nancis-Princess and Sophy-Maro gave the least. Sole 'Maro' pea produced the heaviest seed than the other treatments (Table 2). Intercropping generally resulted in a reduction in seed weight, however the reduction was greater with 'Sophy' maize (8%) than Nancis (7%).

In 2001 mean seed weight was slightly greater than that obtained in 2000 for both sole and intercropped peas, but was greater when 'Princess' pea was intercropped with 'Nancis' maize (7%) than 'Sophy' maize (3%).

In both seasons intercropping maize with Maro resulted in consistently greater average land equivalent ratios (LER) and area time equivalent ratios (ATER) compared to Princess (Table 3). Similarly intercropping pea with Sophy had consistently greater average LER and ATER than Nancis. Mean LER and ATER in 2001 were greater than those obtained in 2000 but the greater reduction was obtained when maize was intercropped with Maro (19%) compared to Princess (9%). Averaging the LER and ATER for the two seasons intercropping maize with Maro resulted in 47% and 30% more efficient land use than their respective sole crops.

In both seasons Maro was more aggressive than Princess and Nancis more aggressive than Sophy (Table 4).

Table 3. Average LER and ATER of morphologically contrasting maize-pea cultivars 2000-2001.

2000	*Maro*	*Princess*	*Mean*
Nancis	1.57	1.26	1.42
Sophy	1.63	1.45	1.54
Mean	1.60	1.35	
LSD (0.05)	0.38		
CV (%)	13.02		
2001			
Nancis	1.29	1.25	1.27
Sophy	1.38	1.23	1.31
Mean	1.34	1.24	
LSD (0.05)	0.04		
CV (%)	11.43		

Table 4. Aggressivity of peas relative to maize as affected by morphologically contrasting maize-pea cultivars 2000-2001.

2000	*Maro*	*Princess*	*Mean*
Nancis	0.63	-0.13	0.25
Sophy	0.51	-0.15	0.18
Mean	0.57	-0.14	
LSD (0.05)	0.04		
2001			
Nancis	0.32	0.35	0.34
Sophy	-0.17	0.24	0.04
Mean	0.08	0.30	
LSD (0.05)	0.54		

Discussion

The greater yield obtained for the sole maize can be ascribed to greater biomass and kernel number m^{-2} due to greater cob number $plant^{-1}$ obtained for the sole crops. Maize single seed weight was generally constant for both sole and intercrops in both years. Reddy (1992) reported comparable or greater pearl millet yields in intercropping and reduced cowpea yields in intercropping compared to sole cropping. Single seed weight of both maize and pea were not affected by intercropping in both years, suggesting that competition could have occurred much earlier in the season reducing seed number as well as possibly late in the season by limiting assimilate supply to unfilled seeds. In contrast to the findings of this study Yunusa (1989) reported greater single grain weights for intercropped maize and soybeans than their sole crops which might be ascribed to differences in environment and species. These smaller maize yield components in the current study might be attributed to competition from the rapid initial growth of peas. However the considerable kernel yield obtained at harvest was due to the greater partitioning of dry matter to maize kernels as indicated by the greater harvest indices of the intercrops in both years.

The greater kernel yields obtained by Nancis in both cropping systems were due to large kernel number, as single seed weight did not differ. This might be attributed to its greater harvest indices in both sole and intercrops compared to Sophy. Udo and Ndaeyo (2000) reported increased harvest indices for maize intercropped with cowpea, melon and cassava. Sophy intercropped with pea in both seasons improved partitioning of dry matter to seed compared sole Sophy indicating a greater yield potential in intercropping for this cultivar.

The greater yield reduction in maize caused by Maro in the first season might be due to better Maro growth leading to greater competition for growth resources. However in 2001 the distribution of rainfall about 19.3mm at 40-49 days compared to 0mm at the same growth stage in 2000, which favoured Princess, the semi-leafless pea, as it coincided with maximum vegetative and flowering stage of the

crop, which grew taller than Maro, the normal leaved pea and was therefore more competitive than maize. The results of the study suggests that, besides the maize cultivar effect, environmental factors such as rainfall distribution could affect the competitive ability of the dominated component crop in intercropping conditions. Thorsted *et al.* (2002) reported similar or greater oat yields when intercropped with morphologically contrasting clover cultivars, which contrasts with intercropped maize yields obtained in this study, which were consistently smaller than sole maize. Intercropped pea yields in both years were greater in 2000 and similar in 2001 to sole pea yields. The intercropped pea had greater harvest indices in 2000 and smaller in 2001, this might be due to relatively dry spell experienced at flowering which might have influenced partitioning of dry matter to grain at the expense of vegetative growth.

The greater yield associated with intercropped pea in 2000 could be attributed to greater harvest index, and seeds m^{-2}. In 2001 pea harvest indices were smaller but seed yields were generally greater due to greater biomass. In 2000 pea seed yields were at variance with those reported by Wahua *et al.* (1981) who reported reduced cowpea yields due to intercropping with maize. The semi-leafless phenotype is a compromise which maintains a comparable crop growth rate with the conventional leaved but with better standing ability (Pyke and Hedley, 1983). Kielpinski and Blixt (1982) argued that greater yields ascribed to semi-leafless pea are attributable to improved standing ability and better light penetration and not increased yield potential. The slight reduction in pea yields caused by the floppy leaved maize in 2001 agree with the results of Wahua *et al.* (1981) who had the biggest reduction for a floppy leaf maize compared to an erect leaf maize.

Ahmed and Rao (1982) postulated that the close proximity of component crops in intercropping leads to more intimate intermingling of their root systems which might result in greater use of available resources. The greater or comparable intercrop pea yields compared to sole crop pea suggests that pea might have benefited from the companion maize crop in the intercrops than in the sole crops. Ntare (1989) reported significant cowpea yield reductions when intercropped with pearl millet and that the degree of yield reduction was greater for early maturing erect cultivars than the indeterminate spreading type which had the least effect on millet yields. Udoh and Ndaeyo (2000) reported smaller cowpea and melon seed yields when intercropped with maize and attributed it to competition from the companion maize crop.

Nyambo *et al.* (1980) in a study involving plant combinations and configurations of three cereals (maize,

sorghum and millet) and two legumes (soybean and green gram) reported yield reductions in one or both crops but that reductions were greater with legumes ranging from 33-82% compared to cereals 7-37%. Agboola and Fayemi (1972) found that legume yields in intercrops were more depressed than that of the non-legume and suggested that intercropping crops of widely differing growth habits can reduce the decrease in yield. Gardiner and Craker (1981) reported decreased bean yields in maize/bean intercrops, which sharply contrasts the pea yields in this study. Fisher (1977) found that bean seed yields when intercropped with maize were smaller than sole beans and attributed the reduction in seed yield to shading by maize thereby resulting in reduced supply of photosynthates to the developing bean seeds.

The large harvest index associated with the intercrops in this study is supported by those of Natarajan and Willey (1986) who reported greater harvest indices for stressed intercrops than their sole counterparts. Zimmermann *et al.* (1985) reported consistently smaller grain yields and harvest indices for three bean crosses with maize than in sole crops.

The competitive ability of peas relative to maize was measured using the aggressivity index. In 2000 Maro was more competitive than maize as the aggressivity index of pea relative to maize was positive. However Princess was less competitive to maize as the aggressivity index of Princess relative to both maize cultivars was negative. In 2001 both pea cultivars were more competitive than maize as their aggressivity indices were generally positive except when Sophy was intercropped with Maro.

Conclusion

Intercropping maize with pea resulted in consistent reduction in maize yield but the reduction was greater when maize was intercropped with Maro the conventional pea than Princess the semi-leafless pea in 2000, whilst in 2001, maize yield reduction was greater when intercropped with Princess the semi-leafless pea than Maro the conventional leaved pea. This conclusion sharply contrasts what several workers, have reported, that the tall cereal usually suppresses the yields of the lower-storey legume. Averaging the LER and ATER for both seasons intercropping maize with 'Maro' pea resulted in 47% and 'Princess' pea 30% more land use efficiency than their respective sole crops.

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