Evaluation of performance of rice (*Oryza sativa*) and taro (*Colocasia esculenta*) in a mixed cropping system

R. SAGOE, R. BAM, J. MANU-ADUEING, J. HALEEGOAH, D. DEDZOE, J. P. TETTEH, A. ANKOMAH, J. K. OSEI & O. SAFO-KANTANKA

(R. S., R. B., J. M.-A., J. H. & A. A.: Crops Research Institute, CSIR, P. O. Box 3785, Kumasi, Ghana; D. D.: Soil Research Institute, CSIR, Kumasi, Ghana; J. P. T.: University of Cape Coast, Cape Coast, Ghana; J. K. O.: University of Ghana Agricultural Research Station, Kade; O. S.-K.: Kwame Nkrumah University of Science and Technology, Kumasi, Ghana)

ABSTRACT

Taro (*Colocasia esculenta* (L) Schott var. *esculenta*) is widely distributed and cultivated in the wet tropics of the world. In Ghana, its cultivation is limited to river basins or banks in large cities. However, a few farmers grow it on a large scale and rank it as their main source of income. A major problem identified in its production is the flooded culture that makes its cultivation intensive and expensive, and the seasonality in marketing the crop. This necessitated the introduction of rice into the cropping system to increase productivity per unit area and increase income of farmers. To facilitate technology transfer and adoption of this technique, an integrated approach was used. The participatory research–farmer–extension approach is described. Rice growth measure, as height, tiller and effective tiller counts were not significantly influenced in the system. Rice growth was better on the rotation and intercrop plots. Although rice height, tillers and effective tillers were higher for the intercrop system, yields under this system were lower because of the negative correlations that exist between rice height, tillers, and grain yield. Taro growth measured as petiole length and leaf number increased with time on all systems; the rate of increase was higher for sole crop than the intercrop system. Rice reduced taro petiole length and increased leaf number in the intercrop. Tuber sizes were the same for all treatments, but final taro yields were reduced. The average performance of the rice crop in the intercrop was the same (0.85), whilst that of taro varied within the study period, giving values of 1.35 – 1.5. The taro crop (1.65) was found to be more competitive or aggressive than rice (0.6) in the intercrop system. The intercrop had LER values of 1.1 and 1.2, signifying a better option in terms of land resource use.

RÉSUMÉ

Sagoe, R., Bam, R., Manu-Adueing, J., Haleegoah, J., Dedzoe, D., Tetteh, J. P., Ankomah, A., Osei, J. K. & Safo-Kantanka, O.: *Evaluation du rendement du riz* (Oryza sativa) *et du taro* (Colocasia esculenta) *dans un système de cultures associées en mélange.* Le taro *(Colocasia esculenta* (L) Schott var. *esculenta*) est largement distribué et cultivé sous les tropiques humides du monde. Au Ghana la culture est limitée aux bassins ou aux bancs des rivières dans les grandes villes. Cependant, peu de cultivateurs le cultivent sur une grande échelle et le classent comme leur sources principales de revenu. Un problème majeure identifié avec sa production est la culture d'inondation qui rend sa culture très intensive et coûteuse ainsi que la nature saisonnière de la commercialisation de ce produit agricole. Ceci a nécessité l'introduction du riz dans le système de culture pour augmenter la productivité par unité de superficie et pour élever le revenu des cultivateurs. Pour faciliter le transfert de technologie et l'adoption de cette technique, la méthode intégrée était utilisée. L'approche participative de researche - cultivateur - vulgarisateur est décrite. Les mesures de croissance de riz telles que, la hauteur, la talle et les comptes de talles effectives n'étaient pas considérablement influencées dans le système. La croissance du riz était meilleure sur les terrains d'assolement et de cultures associées en mélange. Malgré que hauteur, talles et talles effectives étaient plus élevées pour le système de cultures associées, les rendements sous ce système étaient plus faible à cause de corrélations négatives qui existent entre hauteur de riz, talles et rendement de grain. La croissance de taro, mésurée comme longueur de pétiole et nombre de feuille, augmentait avec le temps sous tous les systèmes et la proportion d'augmentation était plus élevée pour la culture seule que pour le système de culture associée. Le riz reduisait la longueur du pétiole du taro et augmentait le nombre de feuille dans la culture associée. Les tailles des tubercules étaient les mêmes pour tous les traitements mais les rendements finals de taro

Ghana Jnl agric. Sci. **37**, 49-57 | Accra: National Science & Technology Press

étaient reduits. Les rendements moyens du riz sous le système de culture associée étaient les mêmes (0.85) alors que ceux du taro variaient au cours de la période d'étude donnant les valeurs de 1.35 – 1.5. Le taro (1.65) était découvert d'être plus concurrentiel ou agressif que le riz (0.6) sous le système de culture associée. Le système de culture associée donnait les valeurs de la proportion equivalent au terrain de 1.1 et 1.2 indiquant un meilleur choix sur le plan d'utilisation de resource en sols.

Original scientific paper. Received 17 Jan 03; revised 7 Oct 03.

Introduction

Taro, *Colocasia esculenta,* is a herbaceous plant with edible tubers. It is commonly referred to as cocoyam, dasheen, *eddoe, kooko, or broobe.* Its distribution and cultivation in the wet tropics is wide. Yields are about 4 t/ha in Ghana, but with good management, yields of 25 – 37 t/ha have been recorded in the Pacific (Sar, Wayi & Ghodake, 1998). Farmers cultivate about 200 hectares per year. Taro has a potential of being an important crop in the diversified food system. It is normally found growing along river banks or low-lying areas on a small scale. This is because the common use is to boil, roast and fry its edible tubers, and to a lesser extent, its foliage as a leafy vegetable. Taro starch grains are small and very digestible and, therefore, used for invalid foods (FAO, 1989). Flour made from taro is used as substitute for pastries and beverages.

Ghana has a vast area of lowland ecology being underutilized. A few farmers grow it on a large scale for the local and export markets, and rank it as their main source of income. A recent study in some parts of Ghana showed the fact that the crop is grown under flooded culture makes its cultivation intensive and expensive. Insufficient planting material, high labour cost, and seasonality in marketing the crop were some of the problems needing urgent attention. This necessitated the introduction of rice into the taro-based cropping system to increase productivity per unit area and income of farmers.

In an attempt to improve and encourage its cultivation in Ghana, the project was designed to evaluate the performance of the cropping system, using a participatory approach involving farmers, researchers, and extension officers.

Methodology

Survey

The study was initiated in the year 2000 after a preliminary survey of root and tuber crop production in Ghana showed that some farmers were cultivating the crop for the local and export markets (Burkina Faso). This created an interest and necessitated the need to improve the production techniques. Problems and their solutions were identified, using the participatory approach. Incorporating the inputs of farmers who cultivate low-lying areas, taro farmers and extension agents at various locations, three cropping systems were identified and tested on farmers' fields.

Soil type and characteristics

Low-lying sites of already established with rice and *C. esculenta,* and co-operating farmers (six per location) were identified at two locations in Ghana. The Ahafo Ano South (Mankrang valley) and Afigya Sekyere (Jamasi valley) Districts were selected as sites and characterized, and their soil fertility status assessed. The Oda and Kakum series were the type of soils identified in the Mankrang valley, and that for Jamasi was the Offin series. Under FAO classification, Oda is a Hypereutric Gleysol, Kakum, an Orthieutric Gleysol (medium-textured), and Offin, an Orthieutric Gleysol (light-textured). In profile morphology, all the soil types were very deep and poorly drained and were, therefore, suitable for rice and taro cultivation. For all the soil types, the concentration of organic matter and other soil nutrients decreased with depth. All the sites were deficient in P and K, and the levels of nitrogen could support only two cropping seasons in the Ahafo Ano South District, whilst that at Afigya Sekyere could support only a season of cropping. Soils in the Jamasi valleys were found to be extremely acidic. Corrective soil amendments were suggested (SRI, 2002).

Experimental design, treatment, and planting materials

Planting materials for rice (*sika moo* – an improved variety) and taro (*Colocasia* sp. – local variety) were made available to farmers for establishment on their fields. Rice seeds were nursed and transplanted, two per hill, and taro suckers of about the same size were planted simultaneously.

The treatments were as follows:

1. Sole *Colocasia* (taro), spacing 60 cm × 60 cm.
2. Sole rice at a standard spacing of 20 cm × 20 cm.
3. *Colocasia* / rice rotation.
4. Rice / *Colocasia* rotation.
5. Rice - *Colocasia* intercrop (two rows of *Colocasia* alternate with four rows of rice).

The spacing was 60 cm × 60 cm for taro, 20 cm × 20 cm for rice, and 60 cm between rice and taro plants in the intercrop.

The experimental design was an incomplete randomized block with a farmer representing a block. The treatments were randomly distributed among farmers, with each farmer cropping the two sole crops and, in addition, any one of either the rotation or intercrop treatment. The treatments were imposed on plot sizes of 10 m × 20 m. Field days were held at planting, rice booting, and harvest. Farmers' views and perceptions about the various treatments were noted during such meetings.

The response variables measured were as follows:

1. Plant vigour, measured as plant height, number of tillers and effective tillers for rice, taro petiole length (from the base of the crop to the tip of the second youngest petiole), and leaf number for taro.
2. Yield and component of yield - weight of rice grain at harvest, and fresh tuber weight (taro) and 100-tuber weight (taro).

Statistical and performance analysis

The data were analysed using the computer software – Statistical Analysis System (SAS). Since the data were not balanced, the General Linear Model was used to determine the least square means of the various response variables. The model used in the analysis was as follows:

$$Yij = \mu + \alpha i + \beta j + \Sigma ij$$

where Yij represents the observation in the α i th block with the β j th treatment, *m* is the overall mean, and Σij as the unexplained error.

The crops' performance as a result of differences in resource uptake was assessed, using the crop performance ratio (CPR) as suggested by Azam-Ali *et al.* (1990):

$$CPRa = Qia / (Pia \times Qsa)$$

where Qia and Qsa are the productivity per unit area in the intercrop and sole, respectively, and Pia is the proportion of intercrop area sown to crop 'b'.

Land equivalent ratio (LER), which is a measure of the yield advantage in intercrops, was determined using the formula:

$$LER = Ya/Sa + Yb/Sb \text{ (Willey, 1985)}$$

where Ya and Yb are crop yields in the intercrop, and Sa and Sb are the sole crop yields.

To measure the competition between the component crops, the competitive ratio was used:

$$CRa = (LERa/LERb) \times (Zba/Zab)$$

(Willey & Rao, 1980)

where LERs are the land equivalent ratios of the component crops, and Zab and Zba are the proportions of intercropped areas initially allocated to crop 'a' or 'b', respectively, in the intercrop.

Results and discussion

Rice growth and yield analysis

Rice growth assessed as plant height, number of tillers and effective tillers increased with time during the growing period on all treatments at the various locations. Rice height was consistently higher on rice following taro in 2001 planting than the others (Table 1). During the early vegetative growth, percent increase in rice plant height (6-9 WAP) was highest (61%) on the intercrop and lowest on the rotation plots – rice following taro (33 %). However, the rate of growth at maturity phase (9 to 12 WAP) was almost the same for all the systems. Rice growth during the maturity phase was, therefore, not influenced by intercropping with taro, and this confirms earlier findings by several scientists that cereals have great advantage over other crops in mixtures (Osiru & Willey, 1972; Osiru & Hahn, 1987; Jalloh, Dahniya & Ezumah, 1991).

In 2001, rice height, tiller and effective tiller count at 10 WAP on rice after taro was better than rice following rice on the same piece of land (Table 1). Differences within the treatment means and between farmers' fields were highly significant (P> 0.001) for both years. This could explain the contrast that existed between the intercropped plots, on the one hand, and the sole or rotation plots, on the other hand, for rice height at this period, although it was not statistically different. Tiller count at this period (2001) was found to be significantly (P>0.05) higher in the rice after taro plots (rotation) than the sole or intercropped plots. Effective tillers were all lower than the maximum tiller growth recorded at about 10 WAP on all treatments. Differendes within the treatments for both years were highly significant (P>0.001), but the contrast observed between the sole crop treatments and the others were not significant. The highly significant (P>0.01) variability in soil characteristics between the farmers' fields could explain the contrast.

Tiller growth, expressed as number of tillers per hill, increased with time and was higher on rice + taro intercrop. Although percentage increases in tiller growth were higher on sole rice plots, tillers and effective tillers were higher on the intercrop treatment. This did not give a

TABLE 1

Effect of Treatments on Rice Plant Height (cm), Number of Tillers, and Effective Tillers Per Hill Averaged Over Two Locations

Treatment	*Plant height (cm) 10 WAP*		*Tillers/hill 10 WAP*		*Effective tillers/hill*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
Sole rice	85.9	98.6	25.6	20.6	12.5	16.7
Rice after taro (R)*	84.7	102.4	20.0	26.5	11.4	20.2
Rice + taro (I)**	94.2	74.6	28.3	25.3	16.3	20.8
Jamasi (Location 1)	94.2	103.5	29.0	14.8	10.7	16.1
Mankrang (Location 2)	84.8	82	23.6	27.4	14.1	19.5
Grand mean	88.8	94.3	25.5	20.2	12.5	17.6
SE	16.2	10.6	7.9	1.4	4.4	1.0
CV (%)	18.5	11.1	32.3	6.6	33.1	5.9

(R)* - rotation
(I) ** – intercrop

corresponding high rice yield (Table 2), because of lower plant populations (Asafu-Agyei *et al.*, 2001) in the intercrop, resulting in a 58 % reduction in yield.

TABLE 2

Treatment Effect on Rice Yield at Harvest Averaged Over Two Locations

Treatment	*Rice yield (t/ha)* 2000	2001
Rice (sole)	2.86	3.57
Rice after taro (rotation)	3.24	3.33
Rice + taro (intercrop)	1.22	1.51
Jamasi (Location 1)	2.13	1.9
Mankrang (Location 2)	2.80	4.1
Grand mean	2.64	2.8
SE	0.68**	0.14**
CV(%)	25.8	5.8

The relationships between rice growth and yield parameters were evaluated quantitatively, using a regression statistics. The coefficient of correlation (r) value estimates the proportion of the total variation in the value of other parameters that can be explained by the relationship (Table 3). The data (Table 3) showed a negative correlation between rice height and tiller (r = -0.6) and effective tiller (r = -0.4) count on the other hand, and finally yield (r = -0.08). Increasing rice height will, therefore, decrease tiller growth and effective tiller development. The reduction in tiller growth as a result of the increase in rice height was significant at a probability of 5 per cent. A significant (P = 0.000) positive correlation of about 83 per cent existed between tillers and effective tillers. And both tillers (r = 0.44) and effective tillers (r = 0.57) were positively correlated to grain yield. Since effective tillers are closely related to yields than rice height or tillers because of the higher correlation coefficient, treatments that had higher effective tillers had higher yield. And so although the intercrop had high rice heights and tiller counts, the corresponding grain yields were low because of the negative relationship that existed between the parameters and crop density. This confirms the findings of Jalloh *et al.* (1991) which identified plant density as an important factor that affects crop performance in intercrop situations.

TABLE 3

Correlation Coefficients Between Rice Growth and Yield Parameters

Parameter	*Tillers*	*Effective tillers*	*Grain yield*
Plant height	- 0.6*	- 0.4	- 0.08
Tillers		0.83****	0.44
Effective tillers			0.57*

*, **** - significant at $P \leq 0.05$ and $P \leq 0.000$ respectively

Actual rice yields were between 1 t/ha on the intercrop and 3.8 t/ha on the sole crop plots, 200 % higher than yields of the local varieties cultivated by the farmers. The potential yields of rice were the same. Introducing taro into rice cultures will significantly reduce rice yield.

Taro growth and yield analysis

Fig. 1 to 4 show Taro growth measured as petiole length (an indication of crop height) and leaf number per plant. Petiole length was generally higher in 2000 than in 2001.

The rate of growth measured as petiole length over a period of time was greater in the sole crop than in the intercrop (Fig. 1 and 3). Taro after rice in a rotation had higher petiole lengths than sole or intercrop plots between 4 and 20 weeks after planting taro (Fig. 1 and 3). During the early growth period (4 – 12 WAP), rice crop reduced taro height and increased leaf number in the intercrop. The percent differences were higher for leaf growth than plant height.

Leaf growth measured as leaf count was not significantly influenced by the rice crop; however, at 4 WAP, taro after rice in a rotation had higher leaf growth when compared to sole cropping (Fig. 4). Intercropped taro had a comparatively higher

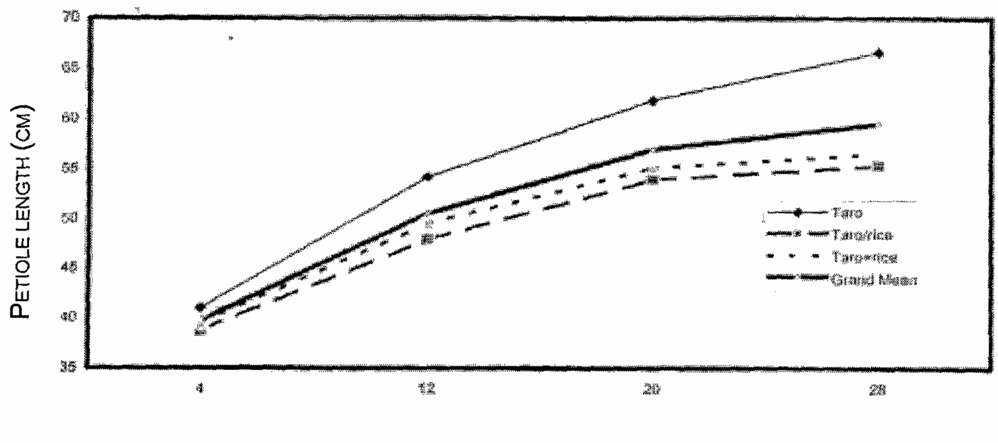

Fig. 1. Treatment effect on taro growth expressed as taro petiole length - 2000.

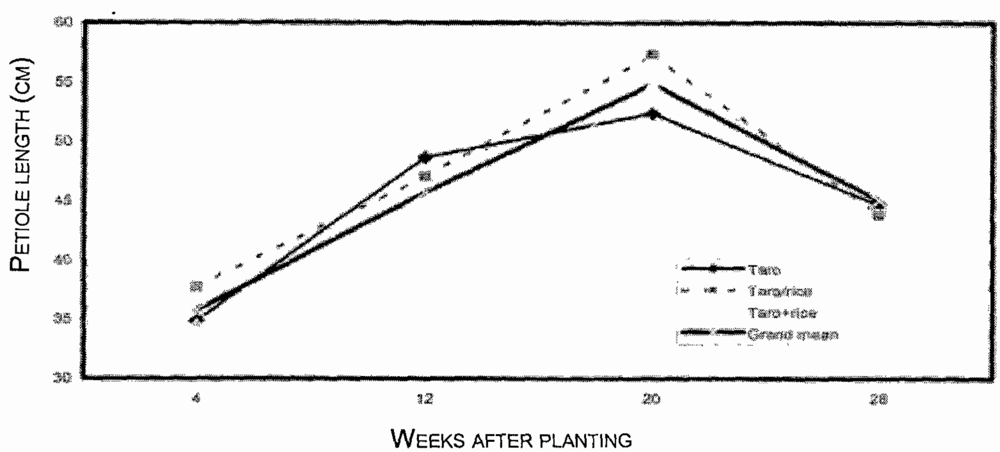

Fig. 2. Treatment effect on taro growth expressed as petiole length - 2001.

leaf number during the same period.

Taro tuber sizes assessed as 100 - tuber weight were not significantly different between the various treatments studied. In 2001, tuber sizes were reduced by 20 % on intercropped plots, although mean leaf per plant was higher on such treatments. The differences were probably due to the significant differences within the treatments and farmers' fields. Taro yields ranged from 16.4 to 32.2 t/ha (Table 4). Introducing rice reduced total taro yield by about 24 – 32 per cent. The differences are due to the lower population density and tuber sizes of taro on such treatment.

Taro tuber weight and final yield were positively correlated. A regression statistic had a coefficient of correlation (r) as 0.9 at a probability of 0.01. Treatments with big tuber sizes had higher final yield; therefore, factors that increase tuber size will positively influence final yield. These factors include adequate moisture during the growth period, balanced soil nutrient levels, and preferred soil pH for taro. This was because taro tubers in

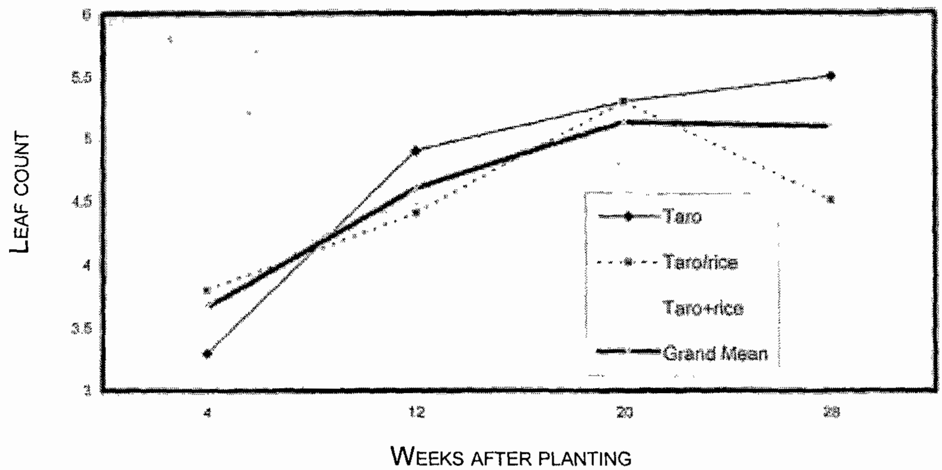

Fig. 3. Treatment effect on taro growth expressed as number of leaves per plant - 2000.

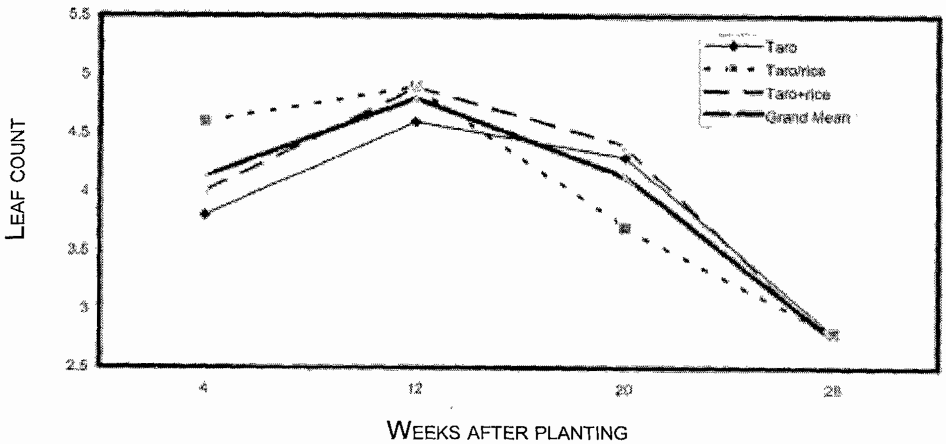

Fig. 4. Treatment effect on taro growth expressed as number of leaves per plant - 2001.

Mankranso District were bigger than those of Jamasi, because of the acidic nature of the Jamasi soils (Table 4). Liming at a rate of 0.5 t/ha and poultry manure at a rate of 5 t/ha, suggested during the initial soil characterization in the study area, increased yields in the Jamasi District (Table 4) in 2001 (SRI, 2002).

Crop performance

The performance of the component crops were assessed, using the following indices: land equivalent ratio (LER), crop performance ratio (CPR), and competitive ratio (CR). Crop yields were generally better in 2001 than in 2000, as it had a better competitive and crop performance ratio for taro during that period (Table 5). Rice crop performance in terms of CPR and CR were the same, although the actual yields were different. This was because, for both years, the same rice variety (*sika moo*) was used. Local mixtures were used in establishing the taro crop for both periods; hence, the differences in the

TABLE 4

Treatment Effect on Taro Yield and Yield Component at Harvest

Treatment	*100 tuber (corm) weight (kg)*		*Yield t/ha*	
	2000	*2001*	*2000*	*2001*
Sole taro	24.4	55.7	24.3	32.2
Taro/rice (R)	23.6	55.7	18.3	31.5
Rice + taro (I)	24.3	44.3	16.4	24.2
Jamasi (Location 1)	18.8	55.3	11.9	33.2
Mankrang (Location 2)	29.1	52.1	23.9	27.9
Grand mean	23.6	53.7	17.5	30.5
SE (±)	2.15	15.9	3.9	9.4
CV (%)	9.14	29.6	22.3	30.9

TABLE 5

Average Performance of Component Crops Under Rice–Taro Intercrop

Treatment	*Year*	*Rice (t/ha)*	*Taro (t/ha)*	*LER**
Sole rice	2000	2.86	-	-
	2001	3.57	-	-
Sole taro	2000	-	24.3	-
	2001	-	32.3	-
Rice + taro intercrop	2000	1.22	16.4	1.1
	2001	1.51	24.2	1.2
CPR**	2000	0.85	1.35	-
	2001	0.85	1.50	-
CR***	2000	0.6	1.6	-
	2001	0.6	1.7	-

CPR** - crop performance ratio; CR*** - competitive ratio; LER* - land equivalent ratio

values (Table 5). Taro crop consistently performed better in the system in terms of CPR and CR. This explained the comparatively similar plant vigour for taro for all treatments (Fig. 1 to 4) assessed over the two cropping seasons. The LER values also confirmed the yield advantage in growing rice and taro together as an intercrop. For both years under the same management levels, intercropping rice and taro had LER value of 1.1 and 1.2 (Table 5), signifying that 10 and 20 % more land, respectively, will be required in sole cropping for equivalent yield as intercrops.

Farmers' perception and observations

Yield per unit area was very high. Farmers attributed the low yield on their own fields and on the intercrops to low plant stand and, therefore, agreed to practise correct spacing for optimum yields. Most taro crops are now being grown in rows at a spacing of about 60 cm × 60 cm. To increase rice yields, local rice crops are also being spaced closely, 20 cm × 20 cm, to increase plant population.

The frequency of weeding was reduced in experimental plots, due to the close spacing of crops. Taro fields are now being weeded regularly.

Good, healthy, and disease-free planting material is used for field establishment. Farmers also appreciate the fact that the taro crop does well in rice fields, as long as they will get varieties that mature early and do not show autoallelopathic characteristics observed by Pardales & Dingal (1988). Some still prefer the late-maturing type of varieties for obvious reasons. The need for improved varieties which will fit into the cropping system has been stressed.

Most of the techniques being practised on the experimental plots by the farmers are being transferred to their bigger plots, and colleagues who are not part of the programme are being advised to pick up the good cultural practices. Some of the practices are correct spacing for rice and taro, transplanting rice, levelling fields for even distribution of flood water before planting, and planting improved rice varieties. Finally, the fact that taro is a hunger crop was emphasized by rice farmers who introduce taro into their rice cultures.

Conclusion

Farmers have shown keen interest in the new system, and have adopted some of the improved management practices. The need to introduce improved taro varieties with good food qualities and high yields that would fit into the rice system is stressed. Local germplasm have been collected and assembled by the Plant Genetic Resources Centre and the Crops Research Institute for evaluation. Improved introductions or germplasm from the Pacific or elsewhere with desirable characteristics is needed to be included in the evaluation. It is, therefore, envisaged that an integrated programme of taro production and use would make its production more viable and attractive as suggested by Sar *et al.* (1998).

Acknowledgement

The principal author is grateful to the Root and Tuber Improvement Programme (RTIP) of the Ministry of Food and Agriculture, Ghana, and the International Fund for Agriculture (IFAD) for their financial support; and to all the District Directorates of the Ministry of Food and Agriculture at the various districts where the trials were sited. The author also appreciates the input of the Technicians of the Crops Research Institute, CSIR, Kumasi, Ghana.

REFERENCES

Asafu-Agyei, J. N., Dapaah, H. K., Ennin, S. A. & Adu-Dapaah, H. (2002) Yield determinants of intercropped maize and cassava. *Agric. Fd Sci. J. Ghana* **1**, 55- 64.

Azam-Ali, S. N., Mathews, R. B., Williams, J. H. & Peacock, J. M. (1990) Light use, water uptake and performance of individual components of a sorghum-groundnut intercrop. *Expl Agric.* **26,** 413-427.

FAO (1989) Cocoyams. Utilization of tropical foods: Roots and tubers. *Food and Nutrition Paper* **47**(2), 34–39.

Jalloh, A., Dahniya, M. T. & Ezumah, H. C. (1991) Production of cassava – rice intercrop as influenced by cassava variety and time of introducing rice into cassava. In *Proceedings of the 9th Symposium of the International Society for Tropical Root Crops* (ed. F. Ofori and S. K. Hahn), pp. 200 – 204.

Osiru & Hahn (1987) Evaluation of cassava genotypes for intercropping systems. Root and Tuber Improvement Program (TRIP) Annual Report 1987. IITA, Ibadan, Nigeria.

Osiru & Willey (1972) Studies on mixtures of dwarf sorghum and beans (*Phaseolus vulgaris*). *J. agric. Sci., Cambridge* **79,** 531 – 540.

Pardales, J. R. Jr. & Dingal, A. G. (1988) An allelopathic factor in taro residues. *Trop. Agric.* **65,** 21 – 24.

Sar, S. A., Wayi, B. M. & Ghodake, R. D. (1998) Review of research in Papua New Guinea for sustainable production of taro (*Colocasia esculenta*). *Trop. Agric.*, (Trin.) **75** (1).

SRI (2002) *Evaluation of local cocoyam* (Colocasia esculenta)*/rice cropping systems for lowland ecologies. Characterization and fertility assessment of soils.* Soil Research Institute Technical Report No. 202.

Willey, R. W. (1985) Evaluation and presentation of intercrop advantages. *Expl Agric.* **21,** 119 – 133.

Willey, R. W. & Rao, M. R. (1980) A competitive ratio for quantifying competition between intercrops. *Expl Agric.* **16,** 117-125.