Turmeric - maize and onion intercropping systems. I. Yield and land use efficiency

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ABSTRACT

Experiments were laid out at Bhavanisagar (Tamil Nadu, India) during 1989 - 90 and at Coimbatore (Tamil Nadu, India) during 1990 - 91 to determine land use efficiency, yield and yield attributes of turmeric (*Curcuma longa* L.) and maize (*Zea mays* L.) in various intercropping and sole cropping systems. Turmeric, maize and onion (*Allium cepa* L.) were raised as sole crops adopting recommended package of practices. Maize and onion were intercropped with turmeric in two proportions (50 and 100 per cent of the recommended population levels). Onion was also introduced as additional intercrop with maize with 23 per cent of the population of sole crop. Turmeric yields were reduced from 9 to 25 per cent when intercropped with maize. Turmeric yield reductions due to intercropping were associated with reduction in number of tillers, mother rhizome, primary and secondary rhizomes. Maize yields were higher with intercropping than with sole cropping. Even though yield of turmeric was reduced by intercropping, turmeric - maize and onion intercropping resulted in 17 to 34 per cent greater land use efficiency for the 9 months growing season than in the sole cropping systems. This is important in developing countries where available per capita arable land is low.

Key words : intercropping systems, land use efficiency, maize, onion, turmeric.

Introduction

Intercropping is a crop management system involving two or more economic species grown together for at least a portion of their respective production cycles and planted sufficiently close to each other so that interspecific competition occurs (Andrews & Kassam 1976). Economic plant species are grown in mixtures for many reasons but the most cited reason is to increase land use efficiency (LUE). Turmeric is a slow growing rhizomatous crop during first three months and takes 8 to 10 months

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from planting to harvest and therefore small farmers can hardly afford to raise it as a sole crop. Hence it was considered advantageous to grow it in mixture with cereals, grain legumes, onion, seed spices, vegetables and other crops (Aiyer 1949; Aiyadurai 1966; Kundu & Chatterjee 1982; Shankaraiah, Reddy & Rao 1987; Shaw & Muthuswamy 1981; Rethinam *et al.* 1984; Balashanmugam & Vedamuthu 1989; Rao & Reddy 1990; Yamgar & Pawar 1992). LUE is usually equated with biological efficiency (Hiebsch & McCollum 1987a). The biological efficiency of intercropping is determined by comparing the productivity of a given area of intercropping with productivity if the same area were to be divided between sole crops to give the same ratio of the two crops as in intercropping (Willey 1985). Inter cropping turmeric with maize resulted in 54 to 95 per cent greater land use efficiency than either crops grown alone (Rao & Reddy 1990). However there is a paucity of information to compare the land use efficiency of turmeric based intercropping systems with various crops. The present investigation was therefore taken up to evaluate the relative efficiencies of various turmeric - maize intercropping systems under assured irrigation with onion as additional intercrop along with maize.

Materials and methods

The field experiments were conducted at Tamil Nadu Agricultural University during 1989-90 at Bhavanisagar (11°29'N latitude, 77°08'E longitude and 256 m above MSL, Tamil Nadu, India) and during 1990-91 at Coimbatore (11°N latitude, 76°57'E longitude and 427 m above MSL, Tamil Nadu, India). The soil at Bhavanisagar was sandy loam (*Udic ustropepts*) and that at Coimbatore was clay loam (*Typic haplustaff*). Soil chemical properties (Table 1) were determined on the 0 - 15 cm increment employing standard procedures (Jackson 1973). The range of average weather parameters that prevailed during the experimental period is given in Table 2. The experiments at both locations were conducted with the same set of treatments. The treatments consisted of five intercropping systems and four levels of nitrogen with one of the treatments involving a biofertilizer (*Azospirillum brasilense*). A split plot design with three replications was adopted for the study. The treatment details are given below :

Main plots : Intercropping systems

T - Sole turmeric (100)

$T+M_1$ - Turmeric (100) + Maize (100)

$T+M_2$ - Turmeric (100) + Maize (100) + Alternate rows of maize cut for fodder on 60th day

Table 1. Soil chemical properties at experimental sites

Soil properties	Bhavanisagar	Coimbatore
pH	7.10	8.00
Organic Carbon (%)	0.62	0.72
Available N (kg/ha)	184.00	292.00
Available P_2O_5 (kg/ha)	6.70	19.20
Available K_2O_5 (kg/ha)	308.00	486.00

Table 2. Range of weather parameters that prevailed during crop periods

Weather parameters	Bhavanisagar	Coimbatore
Cropping period	21.06.1989 to 25.03.1990	07.06.1990 to 08.03.1990
Maximum temperature (°C)	29.4 to 41.0	27.6 to 34.8
Minimum temperature (°C)	21.0 to 24.0	17.5 to 24.5
Mean relative humidity (%)	48.4 to 71.5	47.5 to 80.5
Bright sunshine hours	2.6 to 9.1	1.3 to 10.3
Rainfall (mm)	481.5	398.0
Number of rainy days	33	24

$T+M_3$ - Turmeric (100) + Maize (50)

$T+M_3+O$ - Turmeric (100) + Maize (50) + Aggregatum Onion (23)

(Figures in parentheses indicate percentage of the recommended sole crop population)

Sub plots : Nitrogen levels

N_{125} - 125 kg N/ha (recommended dose of N for turmeric)

$N_{187.5}$ - 187.5 kg N/ha (recommended dose of N for turmeric + 50 per cent of N recommended for maize)

$N_{187.5}+A$ - 187.5 kg N/ha + Azospirillum to maize

N_{250} - 250 kg N/ha (full dose of recommended N for turmeric and maize)

Maize and onion were raised as sole crops at 100 per cent population with recommended package of practices for calculating various land use efficiency indices.

A basal dose of farm yard manure at the rate of 12.5 t/ha was applied uniformly before the last ploughing. Fertilizers were applied both for turmeric and maize as per treatment schedule. Uniform dose of P_2O_5 at the rate of 122.5 kg/ha as single super phosphate and K_2O at the rate of 110 kg/ha as muriate of potash were applied as basal dose for both maize and turmeric. Each treatment of N level was applied in five equal splits as basal and top dressing on 25, 50, 75, and 100 days after planting. Ridges and furrows were formed at 50 cm apart. Turmeric was planted on one side of the ridge at 5 cm depth with a spacing of 15 cm between each rhizome piece. Maize was sown on other side of the ridge at a spacing of 24 cm between plants. Onion was planted at a spacing of 10 cm between plants on one side of the ridge where maize was not planted. All the crops were planted on the same day. Dates of planting and harvests of crops are given in Table 3.

At the time of harvest, data on fresh weight of cleaned turmeric, number of mother rhizomes, primary rhizomes and fingers were recorded. Fresh weight of maize fodder harvested on 60 days after sowing, fresh weight of onion, maize grain yield at final harvest and fodder yield were also recorded. These observations were also recorded from sole

Table 3. Dates of planting and harvest of crops

Crop	Bhavanisagar		Coimbatore	
	Date of planting	Date of harvest	Date of planting	Date of harvest
Turmeric	21.06.1989	25.03.1990	07.06.1990	08.03.1990
Onion	21.06.1989	25:08.1989	07.06.1990	10.08.1990
Maize (fodder)	21.06.1989	20.08.1989	07.06.1990	06.09.1990
Maize (grain)	21.06.1989	04.01.1989	07.06.1990	20.10.1990

crop of maize and onion. In addition to maize grain yield, yield attributes of maize like cob length, cob diameter, number of rows per cob, number of grains per row and 100 grain weight were also recorded. Land use efficiency was determined by calculating various land use efficiency indices. Land equivalent ratio (LER) is a frequently used efficiency indicator. As defined by Mead & Willey (1980), it is analogous to RYT of de Wit & van der Bergh (1965). The LER is calculated as follows:

$$LER=i= \sum_{i=1}^{n} (Y^1_i/Y^M_i)$$

Where Y^1_i = Yield of crop i in intercropping

Y^M_i = Yield of crop i in monocropping

n = Number of crops in association

A concept that considers the time factor along with land area is Area - X- Time Equivalency Ratio (ATER) proposed by Hiebsch & McCollum (1987a). It is calculated as follows:

$$ATER = \sum_{i=1}^{n} [(t_i^M/t_i^1)x(Y_i^1/Y_i^M)]$$

Where t_i^M =Duration of crop i in intercropping

t_i^1 = Total duration of the intercrop system

The ATER accurately estimates the biological efficiency which is defined as the rate at which radiant energy is converted to harvestable energy via myriad processes that takes place in green plants (Hiebsch & McCollum 1987b).

Another concept called Area Harvest Equivalency Ratio (AHER) was proposed by Balasubramanian & Sekayange (1990). It is calculated as follows:

$$AHER= \sum_{i=1}^{n} Y_i^I(Y_i^M n_i)$$

Where n_i = Total number of possible harvests of crop i that could be obtained during the full intercrop period, if the crop i was monocropped.

This concept combines the area and time factors in a practical sense for quantifying intercrop yield advantages, particularly in multiseason associations claimed by the authors. The effect of various nitrogen levels on land use efficiency of intercropping systems will be dealt with in a separate paper.

Results and discussion

Turmeric

The reduction in freshly harvested

Table 4. Yield and yield attributes of turmeric and onion as influenced by maize intercropping - Bhavanisagar (1989-90)

Treatment	Fresh rhizome yield (t ha^{-1})	Fresh onion bulb yield (kg ha^{-1})	Yield attributes (No.$clump^{-1}$)			
			Tillers	Mother rhizomes	Primary rhizomes	Secondary rhizomes
T	25.27	—	3.2	3.0	21.9	24.7
$T+M_1$	20.64	—	2.1	2.0	17.1	18.7
$T+M_2$	21.76	—	2.4	2.3	19.8	19.8
$T+M_3$	23.09	—	2.5	2.4	20.1	20.0
$T+M_3+O$	22.93	3226 (7510)*	2.6	2.5	19.9	20.0
$LSD_{0.05}$	0.21	—	0.2	0.2	0.4	0.4

*Sole crop yield

rhizome yield due to higher maize population ($T+M_1$) varied from 22 per cent in Bhavanisagar to 25 per cent in Coimbatore (Tables 4 and 5). However the suppressive effect of maize on fresh rhizome yield was minimum (9 per cent) in $T+M_3$ in Bhavanisagar and Coimbatore (15 per cent). There was no improvement in the performance of turmeric due to harvesting alternate rows for green fodder purpose on 60 days after planting over allowing 100 per cent maize population for grain purpose, indicating dominance by maize in extracting the resources at the cost of turmeric productivity. A plant heavily shaded by its neighbour suffers reduced photosynthetic activity. This

Table 5. Yield and yield attributes of turmeric and onion as influenced by maize intercropping - Coimbatore (1990-91)

Treatment	Fresh rhizome yield (t ha^{-1})	Fresh onion bulb yield (kg ha^{-1})	Yield attributes (No.$clump^{-1}$)			
			Tillers	Mother rhizomes	Primary rhizomes	Secondary rhizomes
T	29.32	—	3.2	3.1	22.0	24.8
$T+M_1$	23.39	—	2.0	2.0	16.8	19.0
$T+M_2$	24.76	—	2.6	2.5	19.4	20.2
$T+M_3$	25.42	—	2.7	2.6	20.5	20.5
$T+M_3+O$	25.11	1584 (5825)*	2.8	2.7	20.5	20.6
$LSD_{0.05}$	0.25	—	0.4	0.2	0.6	0.6

*Sole crop yield

leads to lesser growth, smaller root system, a reduced exploration of the soil, and thus, a reduced capacity to take up nutrients and water. This effect on nutrient and water uptake is quite independent of the competition by a neighbour for water and nutrients. Conversely, a plant with reduced nitrogen supply because of competition, has less foliage and a reduced capacity to intercept radiation, even though it is suffering no competition for this factor (Donald 1963; Gliessman 1986; Trenbath 1986). Here turmeric suffered competition effects only for radiation from maize and had 7.5 to 13.5 per cent less uptake of N compared to the sole cropped turmeric in these experiments. The competitive effect of maize at higher population was reflected in the observation on the reduction in the yield attributes of turmeric viz., number of tillers, other rhizomes, primary fingers and secondary fingers per clump compared to the sole cropping of turmeric.

Maize

Grain yield of maize was significantly affected by the two population levels in these experiments. The yield level in maize was higher in the intercropped maize at 100 per cent population level than in the sole cropped maize (Tables 6 and 7). The higher grain yield of maize in intercropped plots may be attributed to the efficient utilization of nutrients applied to turmeric, which otherwise remained underutilized by the slow growing turmeric. The variation in the yield of maize may be attributed to variations in population levels and consequent change in leaf area index. Leaf area index per se was not a major determinant of competitive ability of maize (Muelba, Brokman & Kague 1985) but both plant height and canopy width (Galway, deQuiros & Willey 1986) and probably leaf angle and orientation were important crop features influencing the shade effect of maize on companion crops (Midmore 1990). The maize hybrid used in this experiment showed more vigour and growth in suppressing turmeric growth due to its higher values of LAI attained within a period of 60 days.

Table 6. Yield and yield attributes of maize as influenced by intercropping with turmeric - Bhavanisagar (1989-90)

Treatment	Grain yield (t ha^{-1})	Yield attributes				
		Cob length (cm)	Cob diameter (cm)	No. of rows cob^{-1}	No. of grains cob^{-1}	100 grain wt. (g)
T+M_1	5.766	16.8	15.2	18.0	16.7	27.2
T+M_2	3.693	17.2	15.1	18.4	16.2	27.6
T+M_3	3.739	17.2	15.2	18.6	16.5	27.5
T+M_3+O	3.817 (3.226)*	17.7	14.9	18.3	16.2	27.4
$LSD_{0.05}$	0.12	NS	NS	NS	NS	NS
Sole crop	5.613	15.6	13.4	16.7	14.9	25.8

***Yield of onion**

Table 7. Yield and yield attributes of maize as influenced by intercropping with turmeric - Coimbatore (1990-91)

Treatment	Grainyield ($t\ ha^{-1}$)	Yield attributes: Cob length (cm)	Cob diameter (cm)	No. of rows cob^{-1}	No. of grains cob^{-1}	100 grain wt. (g)
$T+M_1$	6.625	19.0	16.7	18.6	16.2	28.2
$T+M_2$	3.999	19.2	16.4	18.8	16.8	28.1
$T+M_3$	4.025	19.3	16.3	18.2	16.5	28.2
$T+M_3+O$	4.019	19.6	16.5	18.4	16.2	28.6
	(1.584)*	—	—	—	—	—
$LSD_{0.05}$	0.084	NS	NS	NS	NS	NS
Sole crop	6.127	15.2	15.2	17.1	15.3	26.6

*Yield of onion

Onion

The yield of onion was higher in Bhavanisagar than in Coimbatore (Tables 4 and 5)due to favourable soil conditions for its proper growth and development. A very low yield of onion in the intercropping system was ob-

Table 8. Land use efficiency (LUE) values of turmeric - maize intercropping systems

Intercropping systems	Duration (days)	ni*	Bhavanisagar LER	Bhavanisagar ATER	Bhavanisagar AHER	Coimbatore LER	Coimbatore ATER	Coimbatore AHER
T: Turmeric sole crop	270	1	1.00	1.00	1.00	1.00	1.00	1.00
M: Maize sole crop	105	1	1.00	1.00	1.00	1.00	1.00	1.00
O: Onion sole crop	65	1	1.00	1.00	1.00	1.00	1.00	1.00
$T+M_1$								
Turmeric	270	1	1.84	1.22	1.33	1.88	1.22	1.34
Maize	105	2						
$T+M_2$								
Turmeric	270	1	1.52	1.12	1.19	1.49	1.09	1.17
Maize	105	2						
$T+M_3$								
Turmeric	270	1	1.58	1.17	1.24	1.53	1.13	1.20
Maize	105	2						
$T+M_3+O$								
Turmeric	270	1	1.99	1.24	1.33	1.79	1.18	1.25
Onion	65	4						

* Total number of possible harvests of crop i that could be obtained during the full intercrop period if the crop i was monocropped.

LER = Land Equivalent Ratio; ATER = Area Time Equivalency Ratio; AHER = Area Harvest Equivalency Ratio served compared to sole cropping of onion. This reduced yield of onion may possibly be due to reduced proportion (23 per cent) of the recommended population planted in the intercropping system and the competition for resources from the associated crop.

Land use efficiency

Although large differences in turmeric and maize yields occurred between various intercropping systems in the two locations, these systems resulted in LERs between 1.52 and 1.99 (Table 8). These LERs indicate that 52 to 99 per cent more land would have to have been planted to the sole crops to produce the same quantities of turmeric and onion as were produced in the intercropping systems. However LER often overestimates the land use efficiency since it assumes that only one sole crop can be produced during the growth cycle. Actually two maize and four onion crops planted in succession are possible during the 9 month turmeric growing cycle. If factors like time of the growing cycle and number of crops grown during that cycle are considered as in ATER and AHER these systems resulted in lesser advantage (Table 8). However ATER assumes that continuous crop production for all the intercrop species is possible, which is seldom true. In this study LER was overestimated and the ATER was underestimated. However the AHER combines the area and time in a practical sense for quantifying intercrop yield advantages, particularly in multiseason associations. The data from these experiments as well as the calculation of various land use efficiencies indicated that intercropping turmeric with maize in two population levels viz., 50 and 100 per cent of the population levels and onion as additional crop in the system effectively balanced competition between the species, leading to 17 to 34 per cent greater land use efficiency for intercropping as compared to sole cropping systems.

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