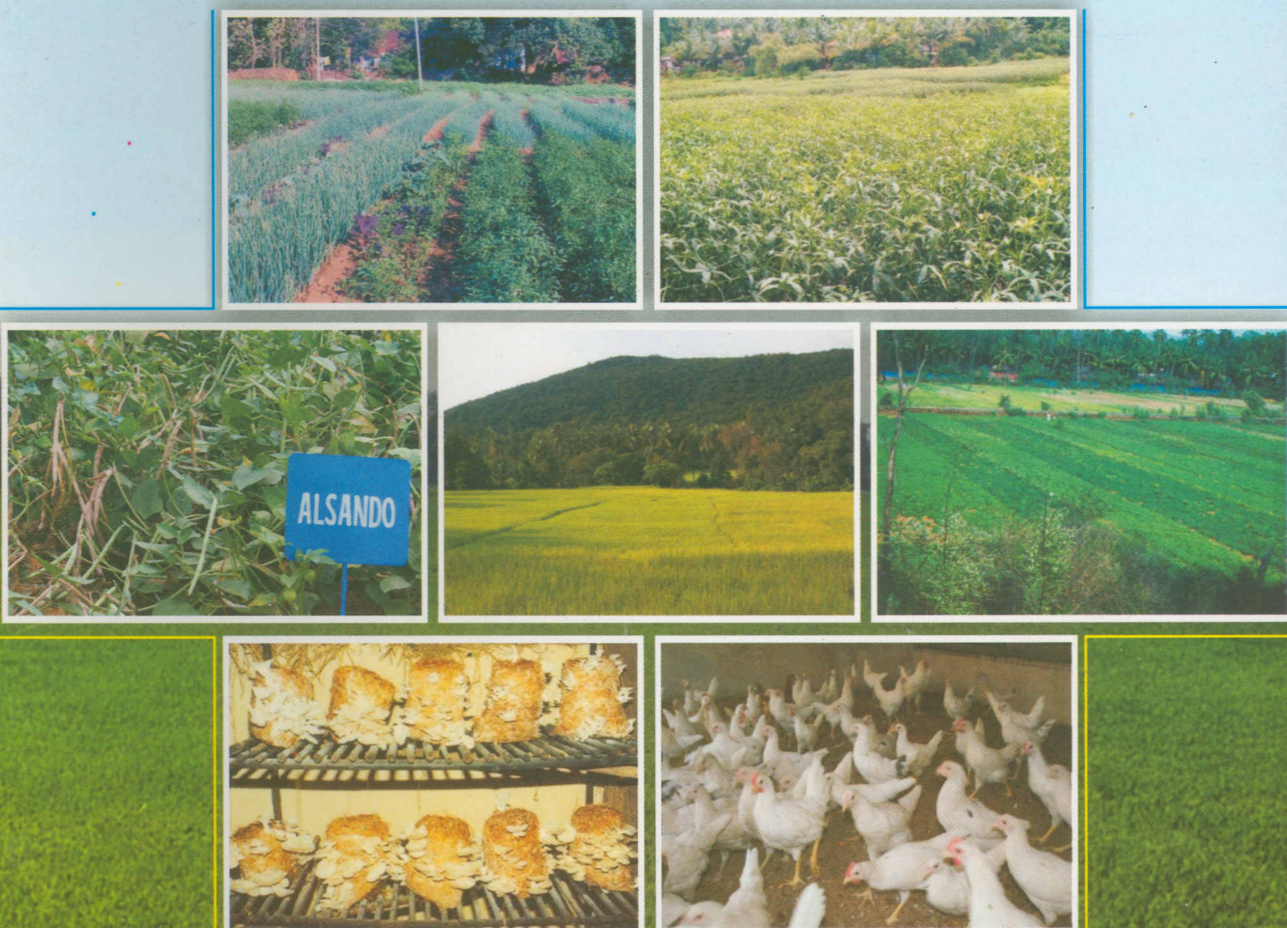
Technical bulletin No. 22

RICE BASED CROPPING/FARMING SYSTEMS FOR HIGHER PRODUCTIVITY AND PROFITABILITY



Indian Council of Agricultural Research
ICAR Research Complex For Goa
Old Goa - 403 402, Goa, India

भाकृअनुप
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FOREWORD

Rice, which is an essential element of food security, is the major cereal crop of India as well as the State of Goa and adjoining regions. I am happy to note that ICAR Research Complex for Goa is bringing out a Research Bulletin entitled *"Rice Based Cropping I Farming Systems for Higher Productivity and Profitability"* highlighting the rice and rice based cropping system research carried out by the Institute.

Rice occupies a special status in the food habits of Goa and adjoining regions where rice-fish curry is preferred by the vast majority in the region. Of late. rice production has been facing specific constraints which have adversely affected its production in the region, I am happy to note that the Institute has introduced and evaluated different rice based cropping system over a period of time. The efforts made to identity profitable rice based cropping system and thereby improve the profitability of rice growers is commendable. Similarly, through recycling of resources, the farming system approach has shown the feasibility of augmenting the profitability of farmers in Goa. Further, improved productivity will also reduce the cost of cultivation which will result into sustainable crop production. The efforts made in assessing the sustainability of the system through soil studies needs a special mention specifically in taking the results to the door step of the farmers.

This compilation *"Rice Based Cropping / Farming Systems for Higher Productivity and Profitability"* will serve as a comprehensive document for developing high production package and formulating future research strategies as well as providing relevant information to the researchers, extension workers and the farming community.

I am sure that this Bulletin will also serve as a reference material to all those who are involved in rice cultivation and will go a long way in improving the rice production and livelihood security of small and marginal farmers of the region.

I congratulate all the authors for this commendable publication,

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PREFACE

Rice is the staple food crop and is widely cultivated in lowlying areas of Westcoast region. The agro-climatic conditions prevailing in the region are ideal to realise higher productivity of the crop. However, during the recent years owing to labour scarcity coupled with other socio-economic constraints, the cropped area under rice is dwindling, posing a serious challenge to meet the food security of the region.

Improved productivity and profitability through identification of suitable cropping / faming systems seems to be the possible solution to meet this challenge. Keeping this in view, ICAR Research Complex for Goa, right from its inception has undertaken research on rice based systems especially through evaluation of a series of local and introduced varieties in different pulses, oilseeds, vegetables, etc. so as to identify a suitable genotype for different situations of cultivation. Research efforts at various levels have given a renewed direction to system approach to improve production and productivity.

This Technical Bulletin is a compilation of research work carried out by various scientists at this Institute in this direction. The Research efforts and the achievements will identify the gaps and needs which would pave the way for enhancing the productivity of rice based systems for the benefit of rice growers.

While bringing out this bench mark publication, I sincerely acknowledge the invaluable contributions rendered by various visionaries, research workers and scientists and Indian Council of Agricultural Research, New Delhi for encouraging the research on this aspect.

Our sincere thanks are to Dr.V S. Korikanthimath, the former Director, ICAR Research Complex for Goa for his inspiration, constant encouragement, leadership in introduction and evaluation of various rice based crops / varieties suited to the region, effective transfer of technology by taking up large scale field demonstrations, etc .

Inbebted thanks are due to various Scientists of the Institute *viz*. Dr. P.A.Mathew, Dr.Satish Modak, Dr. Mani Chellappan, Mr. V. Y. Gaonkar, Smt. Sunetra Talaulikar for their immense research contributions.

The conduct of various onfarm trials and frontline demonstrations on rice based systems was possible with the co-operation of Directors, Dy. Directors and Zonal Agricultural Officers of Directorate of Agriculture, Government of Goa over the years.

The co-operation and enthusiasm evinced by the farmers of Goa deserves high appreciations.

AUTHORS

CONTENTS

I. Introduction

Rice (*Oryza sativa* L.) is the staple food crop of West coast region and the crop dominates the low lying eco-system with varying production situations and productivity levels. The crop occupies more than 35 per cent (47,104 ha) of the total cultivated area in the Goa State. It is cultivated under three distinct ecologies during *kharif* season, *viz.*, lateritic uplands (*Morod* lands), rainfed low lands (*Kher* lands) and saline areas (*Khazans*). About 31,116 ha is cultivated during *kharif* while another 15,938 ha is cultivated during *rabi* season (Anon. 2010).

Rice cultivation in the region has been predominantly a subsistence occupation with little or no emphasis on commercial approach. Traditional rice cultivation in the region faces several socio-economic constraints like fragmented land holdings, absentee landlordism, costly and non availability of labour, lack of co-operative farming efforts, reluctance of youth to take up the noble profession of rice farming to mention a few (Manjunath *et al.*, 2009_b). Lack of adequate marketing and processing infrastructure in the State have further compounded the problems faced by a rice farmer. The yield levels in the uplands depend on the nature of the crop i.e. whether it is direct seeded or transplanted. Rice under this type of land is transplanted wherever there exists resources of natural flow of irrigation and direct seeded in the absence of such irrigation facilities. The average yield in direct seeded condition is estimated to be about 2,000 kg/ha, while under transplanted conditions, it could be as high as 4,100 kg / ha. Although, there exists a scope for improving the productivity, the socio-economic constraints leading to higher cost of production is a major threat to the sustainable rice production. Often, the cultivated areas are being left fallow owing to increase in labour costs. In Goa State an area of 6,750 ha has been reported as current rice fallows.

The Goa State is dominated with marginal and small holdings with 81 per cent of the holdings below 1.0 ha and another 11.5 per cent between 1.0 to 2.0 ha. Thus, the small and marginal farmers constitute the bulk (92.53%) of the land holders. The requirement of these resource poor small and marginal farmers needs to be addressed through system approach.

At present the region is not self sufficient in rice production and part of the requirement is being met through importing from neighbouring rice growing areas. The crop cultivation needs to be sustained in the region keeping in view the growing demand with increasing population (both native and floating population due to booming tourism in the region) over the years, local rice food habits, limited choice of cultivation of other crops in the low lying areas, etc. Further, rice cultivation also sustains the local ecology and contributes for the recharge of ground water, which is a shrinking resource in many parts of India.

II. The prevalent rice based systems

The traditional rice based cropping systems followed in the region include rice-pulse (mostly local cowpea commonly called *Alsondo*) and rice-groundnut under residual moisture situations and rice-vegetables under protective irrigation through surface dug out ponds. There is ample scope to improve both the productivity and profitability in the system by identifying suitable genotypes and through intensive management so as to enhance the returns for a rice grower and sustain the crop cultivation in the region.

The official figures indicate that out of the total area of rice in the State, 35,710 ha is available for taking up cultivation of crops like pulses (1,1540ha), seasonal vegetables (8,213 ha) and groundnut (2,640 ha) leaving the rest of the area as fallow annually. Due to heavy rainfall (2800-3000mm) from June to September with abundant water availability in *kher* lands, rice occupies predominant place. Further, after the harvest of rice crop, the residual moisture is available in the soil for nearly three to four months. Similarly, the coastal areas exhibit high water table which offers great potential for sequential cropping in these areas. This natural resource offers a vast potential for crops like pulses and groundnut which are most suited crops. The work carried out under this eco system revealed that the productivity levels of groundnut are quite high (2.2-2.3 t/ha) which can be further enhanced to over 2.8 t/ha with two supplementary irrigations in February at flowering and peg formation stages.

Plate 1. Local cowpea (Alsondo) and groundnut - predominant rice based crops under residual moisture in rice fallows

III. Improved rice based sequential cropping systems

The biological efficiency of a cropping system is measured in terms of yield per unit area over a specified period of time. However, this efficiency is governed by and dependent on several factors, most decisive being the type of crops, crop / enterprise combinations, land use, nutrient and water management and agro-climate.

The prevalent cropping systems in the region are time tested and are ideally suited to the agro-climatic situations. However, there is a lack of availability of high yielding quality seed in the sequential crops *viz.* cowpea, groundnut and vegetables. As such attempts were made to either select or introduce and identify high yielding varieties in these crops.

1. Rice-cowpea sequential cropping system

In Goa and adjoining West coast areas, cowpea is the major pulse crop traditionally grown in rice fallows under residual moisture situations. Goan cowpea (locally called *Alsondo*) is a bold seeded type with a viny growth upto 3.0 m producing higher biomass. It produces lengthy bold and fleshy pods. It is fairly tolerant to drought situations and suits for residual moisture situation in rice fallows. This local cowpea is preferred in many of the culinary preparations owing to its unique taste, bold size and better cooking quality. As such, it fetches a premium price in the market.

However, the yield levels of the crop is generally low. One of the main reasons for this low productivity is lack of a suitable high yielding variety of the crop. Sporadic attempts to introduce few high yielding types of small seeded cowpea were although made, yet these varieties could not become popular among the farmers owing to local preferences for bold grain types that are preferred in the market with premium price.

Goa region was found to have wide variability both for the phenotypic and genotypic traits in the local cowpea crop. Variations exist for plant types, branching habit, flowering behaviour, duration, seed size, colour, seed yield and haulm yield. As such, attempts were made to collect this variability and select a high yielding type with better seed size.

Systematic survey was undertaken in the major cowpea growing areas of Goa for five years during the period from 2000 to 2006. The crop grown in different areas of the region were studied for the selected traits. Identified samples of selected cowpea accessions were collected during the crop growing season. The collections were critically evaluated for the phenotypic and genotypic traits. Further, the collections were purified and continuously evaluated to finally select seven accessions based on their consistency in performance. The short listed selections were evaluated in Randomized Block Design with three replications for four years in farmer's field in rice fallows under residual soil moisture situations (as per the local practice) with different spacings.

Periodic growth and yield observations were recorded and the data analysed as per the standard statistical procedures. The selected accessions were studied both for organo-leptic and the nutritive value using standard procedures.

Table 1. Variability in the local cowpea accessions

Sl. No	Character	Observation
1	Plant type	Bushy to highly viny
2	Plant height	14.7 to 20.8 cm
3	Days to 50 % flowering	43 to 84 days
4	Days to maturity	93 to 116 days
5	Mean primary branches	0.2 to 5.8 / plant
6.	Trifoliate leaves/plant	6.8 to 14.2
7.	Pod number/plant	3.0 to 36.6
8.	Length of pod	11.3 to 27.4 cm.
9.	Seeds/pod	6.4 to 18.6
10.	Seed : Pod ratio	0.66 to 0.78
11.	100 seed weight	6.0 to 33.5 g
12.	Harvest Index	0.17 to 0.61
13.	Seed colour	Light brown to dark brown
14.	Seed yield	upto 1569 kg/ha
15	Biomass yield	0.29 to 8.44 t/ha
16	Protein content of seed	24.9 to 28.7 %
17	Increase in weight on cooking	150 to 200 %
18	Mean volume expansion on cooking	150 to 278 %

Pooled mean yield performance

The short-listed accessions were studied for their yield performance over four years (2004 to 2007). The crop was raised under residual soil moisture situation in rice fallows. The pooled mean seed yield indicated that Nadora Bardez-4 is consistent in its yield performance (1007 kg / ha) followed by LC-4 (866 kg / ha). The higher yield in these accessions was a consequence of higher branching, leafyness and root growth.

Accession	Seed yield (kg/ha)	Haulm yield (t /ha)
LC-4	866	2.31
Aldona-2	809	2.78
Nadora Bardez-3	811	2.83
Nadora Bardez-4	1007	2.33
Nachnora-1	701	3.03
Nachnora-2	569	3.28
Mahakhajan Pernem-2	780	2.57
C.D. (P=0.05)	233	NS

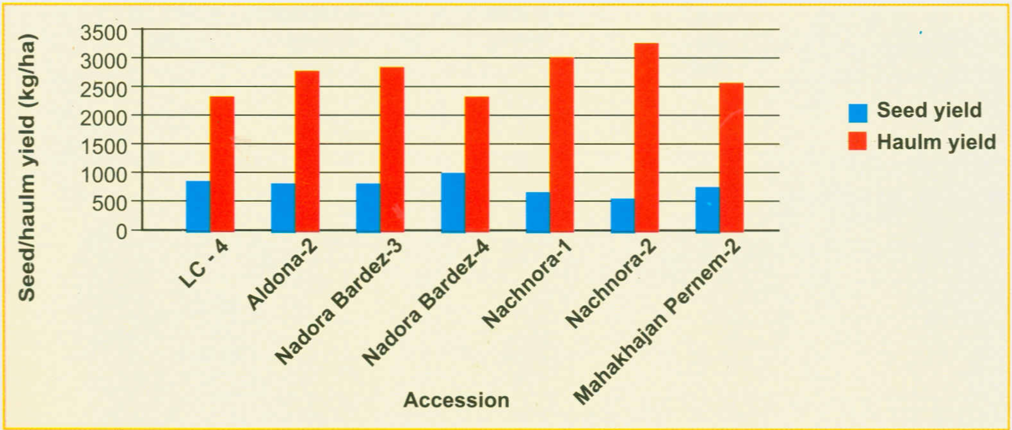

Fig 2. Pooled mean seed and haulm yield of selected local cowpea accessions

The pooled mean haulm yield of the selections over four years (2004-08) indicated that accession Nachnora-2 is consistent in its biomass production (3.28 t/ha) and was followed by Nachnora-1 (3.03 t/ha). The higher biomass yield in the accessions may be attributed to the more vegetative growth recorded in the accessions as reflected in increased vine length and leafyness.

Organo-leptic studies

The selected accessions were evaluated for the cooking quality with the locally preferred dishes. Accession Aldona-2 recorded higher volume expansion (2.78 times) and was followed by Nachnora-2 (2.72). Further these selections were subjected to organo-leptic tests in terms of appearance, softness and taste. Higher organo-leptic scores (6.14, 5.91 and 5.90, respectively) were recorded in selections LC-4, Aldona-2 and Nadora Bardez-4. The accessions were also analyzed for their protein content and the highest (28.4 % protein) was recorded in accession LC-4.

Table 3. Cooking quality and protein content of selected local cowpea accessions

Accession	Mean volume expansion on cooking (%)	Mean organo-leptic score	Protein content (%)
.LC-4	253	6.14	28.4
Aldona-2	278	5.91	25.4
Nadora Bardez-4	245	5.90	24.9
Nachnora-1	238	5. 89	26.0
Nachnora-2	272	5.26	27.1
Mahakhajan Pernem-2	262	5.78	–

Characteristics of selected local cowpea accession

Based on the six years performance, local cowpea accession Nadora Bardez-4 has been found to be quite promising. The characteristics of Nadora Bardez-4, selection of local cowpea is as follows:

Table 4. Characteristics of selected local cowpea accession Nadora Bardez-4

Sl. No	Character	Observation
1.	Growth habit	Bushy to moderately viny
2.	Days to 50 % flowering	63 days
3.	Days to maturity	100 days
4.	Mean primary branches	2 / plant
5.	Trifoliate leaves/plant	44
6.	Pod colour	Greenish white
7.	Pod surface texture	Smooth
8.	Pod bearing nature	Cluster bearing
9.	Pod number / plant	6 to 10
10.	Length of pod	18.3 to 22.2 cm.
11.	Seeds / pod	10 to 14
12.	Seed : Pod ratio	0.78
13.	100 seed weight	23.7 to 24.0 g
14.	Harvest Index	0.43
15.	Seed colour	Light brown to dark brown
16.	Seed yield	1007 kg / ha
17	Biomass yield	3.31 t / ha
18	Protein content of seed	25 %
19	Mean volume expansion	2.45 times
20	Mean organo-leptic score	5.60

Plate 2. Local cowpea selection with high yield potential

Thus, on the basis of study, cowpea selection Nadora Bardez-4 can be recommended for further promotion to large scale cultivation by the farmers of the region.

The selected accessions were field tested through replicated trials during *rabi*-summer seasons of 2004 to 2009 under rice fallows in residual soil moisture situations. The system was maintained with normal package of practices and all the relevant growth and yield parameters were recorded. The average yield recorded with the selected local cowpea was 1007 kg/ha. The economics of cropping system worked out to a total of Rs 42,570/ha net returns from the rice-cowpea system. The system recorded a benefit cost ratio of 2.95 and found to be less risky with higher degree of sustainability.

2. Rice - groundnut system

Perhaps the most significant rice based system that has made impact has been the introduction and popularization of a number of groundnut varieties in the State under the field oriented programmes by developing most appropriate technology for rice based farming under residual soil moisture conditions in which groundnut finds prime place. The impact created over the years has culminated in the implementation of front-line demonstrations in the State.

Goa and adjoining regions being dominated by hot humid weather, groundnut storage with good germination especially during *kharif* season is a practical problem. Keeping this in view, attempts were made to cultivate groundnut on hill slopes (as intercrop in cashew) during *kharif* season so as to form a seed chain for *rabi* cultivation in rice fallows. During *kharif,* altogether three trials consisting of two groups of International groundnut genotypes each having 16 entries in short duration and confectionery groups from ICRISAT, Hyderabad were introduced and evaluated in a 4 x 4 Triple Lattice Design with three replications each with recommended package.

Plate 3. Groundnut under residual moisture in rice fallows- a predominant cropping system

Similarly, a third trial comprising recommended groundnut varieties from ICAR RC, Goa and U.A.S, Dharwad were introduced and evaluated under RBD with three replications.

In addition, a maiden attempt was made in groundnut seed production in KVK area wherein about three ha area was sown with promising varieties like TAG-24, ICGS-76, ICGV-91114 and ICGV-89104 and the seed material was used for front line demonstrations and Institute village linkage programme.

Among the confectionery entries evaluated, ICGV-97061 out yielded all the other varieties yielding 4317 kg/ha dry pods with shelling of 68 per cent as against the check variety ICGS-76 which gave 2745 kg/ha of dry pods with shelling of 68 per cent (Table 5).

Table 5. Performance of ICRISAT confectionery groundnut during *kharif*, 2002

Entry	Days for emergence	Days for flowering	Final stand /m^2	Days to harvest	Pod yield (kg/ha)	Shelling (%)
ICGV						
98432	6.00	33.0	158.6	120.	3819[ab]	68
98404	6.66	38.3	156.3	126.3	3095	68
94049	7.00	38.3	158.0	124.0	2935	66
98402	6.00	37.0	157.6	127.6	3268	68
97040	7.00	39.6	152.0	124.6	3493[b]	58
97058	6.00	38.0	154.6	126.0	3028	60
98397	6.33	35.6	154.0	124.6	2696	60
98369	5.66	36.0	152.6	126.3	3361[b]	70
97045	6.33	36.0	154.6	126.0	3626a[b]	56
97047	6.33	34.3	153.3	123.0	2798	65
97061	5.33	38.3	159.3	129.0	4317[a]	68
98439	5.66	39.3	148.6	119.6	2413	60
98426	6.66	40.5	145.3	121.0	2165	70
98412	5.33	33.6	158.0	128.3	3268[b]	72
97051	7.00	39.6	152.6	122.0	2736	70
ICGS-76	5.33	35.0	155.3	127.6	2745	68

The results of the ICRISAT short duration groundnut trial indicated that the entry ICGV-96442 gave the highest dry pod yield of 3328 kg/ha with shelling of 70 percent compared to the check variety TAG-24 (3055 kg/ha) with shelling of 76 per cent (Table 6).

The results of the third trial with ten promising/recommended varieties indicated that the variety Dh-86 recorded highest yield level of 3120 kg/ha and was found to be at par with ICGS-76 (3040 kg/ha) with TAG-24 yielding 2720 kg/ha. The varieties Dh-3-30 and Dh-40 gave 2320 kg and 2506 kg dry pods/ha, respectively (Table 7).

Table 6. Performance of ICRISAT short duration groundnut *during kharif* 2002

Entry	Days for emergence	Days for flowering	Final stand /m^2	Days to harvest	Pod yield (kg/ha)	Shelling (%)
ICGV 96342	5.00	28.0	159.3	98.33	2630	70
97260	6.33	29.3	160.0	98.00	1192	70
Chico	5.66	29.3	156.6	104.66	2869	70
97262	5.33	28.6	159.6	104.66	3135[ab]	68
96399	5.00	31.0	157.0	103.33	2829	84
97245	6.66	28.3	155.6	95.66	2856	86
97257	5.33	27.3	156.0	98.00	2738	74
96333	6.00	29.6	158.3	104.33	3161[ab]	72
96390	5.66	29.0	160.0	101.66	3188[ab]	70
96395	5.66	29.3	158.3	100.00	2364	80
97243	6.00	28.3	161.0	97.00	3028[ab]	72
93429	5.66	31.0	158.3	96.30	2271	74
96352	5.33	29.6	159.3	103.00	2165	68
96442	6.66	29.0	159.3	102.60	3328[a]	70
96346	5.00	26.6	158.3	94.66	3068[ab]	72
TAG-24	5.66	28.6	157.0	109.00	2420	65

Table 7. Performance of recommended groundnut varieties

Variety	Days for emergence	Days for flowering	Days to harvest	Pod yield (kg/ha)	Shelling (%)
Dh-88	6.2	32.0	116	1386	70
Dh-86	5.3	29.3	110	3120[a]	72
Dh-3-30	6.0	30.2	113	2320[b]	70
Dh-40	6.3	31.6	111	2506a[b]	68
K-134	6.6	28.6	115	2033	58
JL-24	5.8	31.8	117	2320[a]	65
GPBD-4	5.8	29.5	108	2160	68
92242	6.8	34.2	120	2186	62
ICGS-76	6.2	32.2	128	3040[a]	58
TAG-24	5.7	28.6	104	2720[a]	68

Integrated pest and disease management

a) Bioefficiency of insecticides for the management of groundnut pod borer, *Anisolobes stallii*

Replicated field trials were conducted in the Institute's farm to evaluate the efficiency of the bio-pesticides on the groundnut pod borer, *Anisolobes stallii,* which has become a major pest in this region. The trial were laid out on RBD with three replications. Groundnut variety, Dh-3-30 was used for the trial. Treatments (Table 8) were given when the crop started pegging. The per cent infestation was recorded at the time of harvest.

Table 8. Bioefficiency of insecticides for the management of groundnut pod borer, *Anisolobes stallii*

Sr No.	Treatment	Per cent infestation
1	Control	81.3 [h]
2	Endosulfan	61.3 [ef]
3	Malathion	49.5 [cde]
4	Lindane	44.5 [bc]
5	Sevin	53.5 [de]
6	Neem Cake	71.9 [g]
7	Karanj oil cake	63.1 [f]
8	Carbofuron	29.1 [a]
9	Thimmet	39.5 [b]

DMRT (P = 0.05): Alphabets following same data are not significantly different.

In the untreated control, the infestation was as high as 81 per cent. Among the insecticide treatments, Carbofuron treatment gave a fairly good control (29.1%) followed by Thimmet (39.5%). The Karanj oil cake had some insecticidal effect recording 63.1 per cent infestation as against the neem cake (71.9%).

Earwig/wire worm in groundnut *Euborellia stali / Penthicoides seriatoporus*

Earwig / wire worm is a serious problem in groundnut cultivation. As the crop is mostly taken up as a rice fallow crop under residual soil moisture, the effect of irrigation and the critical stages of crop growth that requires protection were studied. Field reaction of different groundnut varieties (ICRISAT- short duration / confectionery, Dharwad short duration) revealed that highest damage due to attack by earwig/wire worm, was recorded in the confectionary group of varieties.

Infestation levels due to attack by earwig/wire worm in groundnut during *rabi* were high and ranged from 0.00 to 79.05 per cent in the ICRISAT short duration group, while in the confectionary group infestation levels ranged from 9.93 to 73.22 per cent.

Plots receiving no irrigation and insecticidal treatment at pegging recorded the least mean percent pod damage of 4.62 per cent damaged pods. The results indicate that the critical stage of crop growth that needs protection is from sowing to pegging.

Management of groundnut root rot under residual soil moisture conditions using biocontrol agents

Incidence of *Macrophomina phaseolina* in groundnut under rainfed conditions is severe and is a major factor of yield reduction. Biocontrol agents viz. *Trichoderma viride* and *Pseudomonas fluorescens* possess potential in reducing the root rot caused by the pathogen. Seed treatment and soil application of *Trichoderma viride* and *Pseudomonas fluorescens* was investigated for two years under rainfed condition. Seed treatment with biocontrol agents significantly increased the germination percentage (11-23 % over control during 2002 and 54-82 % over control during 2003) and reduced disease incidence significantly (40-58 % over control during 2002 and 55-77% over control during 2003). Treatment with *Trichoderma viride* and *Pseudomonas fluorescens* increased pod yield by 14-35 per cent and 22-33 per cent over control during 2002 and 2003, respectively. Disease reduction was on par with the Carbendazim seed treatment and hence use of biocontrol agents as seed treatment with and without soil application could be an effective strategy to reduce root rot disease and enhance yield of groundnut under residual soil moisture conditions.

Seed treatment with bacterial antagonists - A simple technology to manage groundnut root rot under residual moisture conditions

Seed treatment with talc based formulations of 11 bacterial antagonists was carried out to study their bio control activity against the root rot pathogen *Macrophomina phaseolina* and growth promotion in groundnut under residual moisture conditions during 2007 and 2008. Difference in the plant stand, increase in growth parameters at 60 days after treatment was insignificant. High rhizosphere colonization was reflected from the population of RP6, IISR-6 and consortium of EB69+RP7, EB69+RBh42a, RP7+RBh42a obtained 60 days after treatment. Seed treatment with RP2, EB69 during 2007 and EB69+RBh42a, RSh5 during 2008 recorded the highest plant stand at the time of harvest. Least incidence of root rot was recorded in EB150 (9.26%) and in RSh5 (19.40%) during 2007 and 2008, respectively. EB150 reduced the incidence of root rot by 70 per cent and increased the yield by 46 per cent during 2007. RBh42a reduced the incidence of disease by 40 per cent and increased the yield by 137 per cent during 2008. Other bacterial antagonists also reduced root rot incidence and increased pod yield considerably. Based on this study it is concluded that a simple seed treatment with potential antagonistic bacteria during sowing would reduce the incidence of root rot and improve the yield in groundnut under rainfed conditions.

Table 9. Effect of bio-control agents on increase in seed germination, reduction of root rot and increase in pod yield over control in groundnut

S.No.	Treatments	Seed germination % increase		Root rot incidence % reduction		Pod yield % increase	
		2002	2003	2002	2003	2002	2003
1	*T. viride*-ST	23.3	54.4	47.6	55.0	30.9	26.7
2	*T. viride*-ST + SA	11.8	56.5	52.6	72.4	35.4	33.3
3	*P. fluorescens*- ST	15.1	82.7	40.0	68.4	14.6	22.2
4	*P. fluorescens*- ST +SA	14.9	58.6	58.1	77.7	21.0	31.1
5	Neem cake-SA	2.2	-22.8	39.2	69.7	13.5	2.2
6	Carbendazim- ST	39.3	110.3	69.1	62.0	11.4	35.6
7	Control	-	-	-	-	-	-

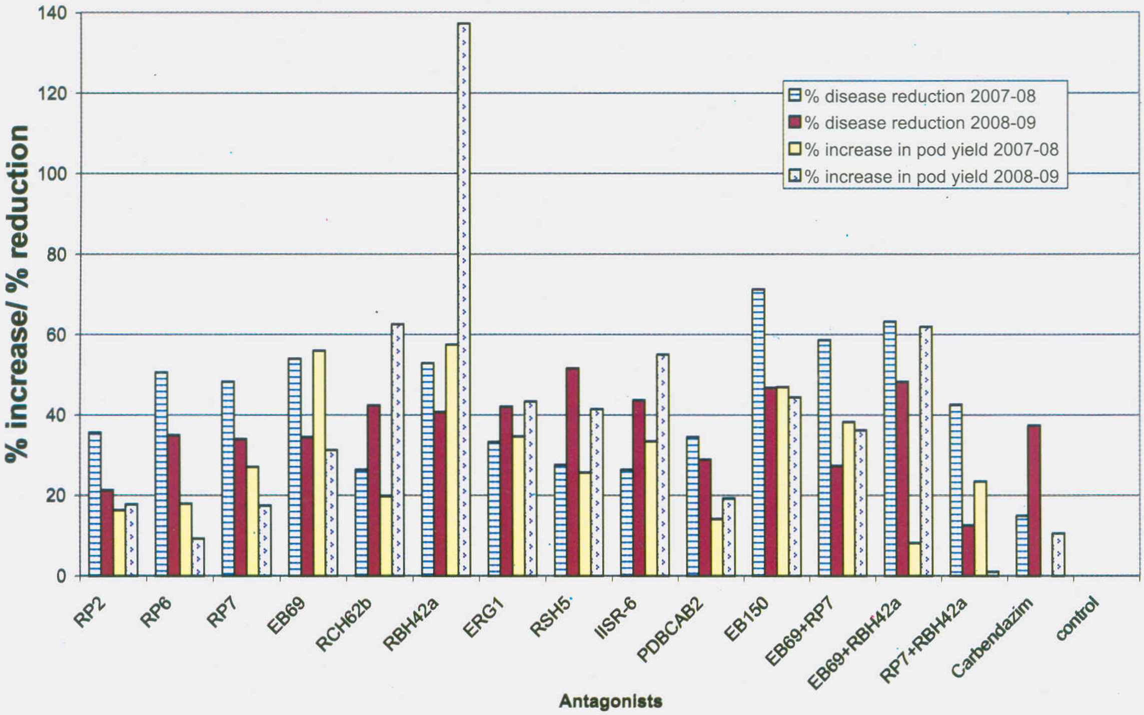

Fig 2. Effect of anatagonistic bacteria on groundnut root rot and pod yield

Assessing the relationship between groundnut pod borer complex and root rot

An experiment was conducted in FRBD to find out the effect of irrigation and different insecticide schedules (drenching of chlorpyriphos at different stages of crop growth) on pod borer infestation and root rot incidence. Root rot incidence was less in the treatment where protective irrigation was given irrespective of the insecticide schedule. In non irrigated treatments the incidence was significantly higher.

Economic analysis of rice-groundnut system

The studies regarding economic advantage of groundnut particularly confectionery groundnut as a second crop under the residual moisture conditions in rice fallows revealed huge economic gains for the farmer by way of giving additional employment to them during lean period. The new introduced groundnut variety TAG -24 produced a mean yield of 2.35 t/ha during *rabi* season under residual moisture conditions which was found to be 35.38 per cent increase over local check variety JL-24 (1.74 t/ha). On the other hand, the confectionary groundnut varieties like Asha (4.26 t/ha), TPG-41 (4.09 t/ha) further boosted the profitability of the sustenance rice grower by value addition.

The economics of the rice-groundnut system was studied in order to arrive at the benefit cost ratio so as to provide additional livelihood security to the end user. The studies resulted in a net income of ₹ 21,907/ha corresponding to a B: C ratio of 2.7:1 in hybrid rice, net income of ₹ 6,578/ha corresponding to B:C ratio of

1.37:1 for red kernel rice and a net income of ₹ 27,805/ha corresponding to B:C ratio of 2.47:1 in case of groundnut. The net income from red kernel rice groundnut system was ₹ 37,375/ha whereas the net income from hybrid rice- groundnut system was found to be ₹46,775/ha.

With these successes as well as with the backdrop of research finding and information available on the subject matter, it would be interesting and pertinent that this crop is taken up on a organized and well planned manner by the developmental agencies to bring in awareness and create a seed chain within the State by involving Farmer's clubs, user groups and registered growers in the first task of rapid seed multiplication in potential talukas during *kharif* season and then shift this quality seed material into the rice based cropping systems particularly in areas which have some source of supplementary irrigation at the fag end of the season. The command areas created with assured irrigation facilities would be ideal choice to rapidly produce large quantity of seed material within the state.

Further, the women self help groups (SHGs) who are proactive can be involved in value addition of this commodity by linking the activity to the growing market both within and outside the State. Needless to state, that such a set up would galvanize the farming activity in the state to a large extent. It is a matter of time this will get a further momentum in years to come.

3. Rice - other leguminous crops

In a field trial to identify suitable pulse and oilseed crops and their varieties for rice follows, four pulse crops viz. cowpea (varieties V-118 and local *alsondo*), greengram (varieties Pusa baisaki and PS-16), blackgram (varietiesT-9 and K-3) and pigeonpea (varieties ICPL-27, ICPL-87, S-31 and DT-7) and one oilseed crop *viz.* groundnut (varieties DH-3-30 and DH-40) were grown after a short duration rice (variety Annanda) under residual soil moisture conditions.

The cowpea variety V-118 was found more promising with many desirable characters like short duration, determinate flowering, higher branching habit (6 primary and 12 secondary), more number of pods per plant (20) resulting in higher seed yield (5.55 Q/ha) as compared to local cowpea (1.88 Q/ha) although the latter had higher test weight (20g) and haulm yield (60 Q/ha).

Among the pigeonpea varieties, variety S-31, found more adaptable to local agro-climatic situations with higher plant height (63 cm), more number of pods per plant (69), seeds per plant (115) and higher 100 seed weight (9 gm) leading to an yield of 2.64 Q/ha as compared to other varieties.

Table 10. Growth and yield contributing characters in different varieties of pigeonpea

Variety	Plant height (cm)	Branches/ plant	Fruited branches /plant	No.of pods /plant	No.of seeds /plant	100 seed wt.(g)	Pod yield (Q/ha)	Grain yield (Q/ha)
S-31	63.0	14	11	69	115	9.0	4.44	2.64
DT-7	53.0	15	13	64	94	7.0	2.78	1.62
ICPL-87	48.3	12	10	46	69	8.0	3.47	2.23
ICPL-27	48.3	11	10	33	39	6.6	2.92	1.83

Although the greengram varieties (Pusa Baisakhi and PS-16) are of shorter duration, their yield potential was found to be low (0.69 and 0.42 Q/ha, respectively).

Among the two varieties of black gram, variety K-3 found to yield better (4.17Q/ha) as compared to variety T-9(3.47 Q/ha).

The groundnut variety DH-3-30 found to have more number of pods per plant, pod weight, pod yield (4.77 Q/ha) with good shelling percentage as compared to variety DH-40.

Among the crops and varieties tested, cowpea variety V-118 found to give higher net returns (₹ 8,390/ha and was followed by blackgram variety K-3 (₹ 6,815 / ha). Although groundnut is suitable crop for rice fallows, the crop recorded lower yields during the year owing to moisture scarcity at pod filling stage. Among the pigeonpea varieties, variety S-31 was found remunerative (₹ 4,600/ha net returns) as compared to other varieties tested.

Table 11. Yield and economics of pulse and oilseed crops in rice fallows

Crop	Variety	Yield (Q/ha)	Gross returns (₹/ha)	Cost of cultivation (₹/ha)	Net returns (/ha)
Groundnut	Dh-3-30	4.77	6678	3000	3678
	Dh-40	4.05	5670		2670
Greengram	Pusa baisaki	0.69	1380	1400	-20
	PS-16	0.42	840		-560
Blackgram	K-3	4.17	8340	1525	6815
	T-9	3.47	6940		5415
Cowpea	V-118	5.55	9990	1600	8390
	Alsondo	1.8	4500	1875	2625
Pigeonpea	S-31	2.64	6600		4600
	DT-7	1.62	4050	2000	2050
	ICPL-27	1.83	4575		2575
	ICPL-87	2.23	5575		3575

Sale price of produce:

Groundnut: ₹ 14/kg

Green gram: ₹20/kg

Blackgram: ₹ 20/kg

Cowpea: ₹ 18/kg

Local cowpea: ₹ 25/kg

Pigeonpea: ₹ 25/kg

The economic analysis of these pulses and oilseed crops as a second crop in rice fallows indicated that cowpea (Var: V-118) is better in terms of both gross returns (₹ 13,880/ha), net returns (₹ 11,055/ha) and returns per rupee invested which was followed by groundnut (variety DH-3-30) (net return ₹ 6731/ha). Among the pigeonpea varieties, ICPL-27 recorded a net return of ₹ 4200/ha while growing of greengram and blackgram varieties was found not remunerative.

In terms of biomass production, rice-cowpea (local *Alsondo*) system was found superior compared to all other systems. In terms of rice equivalent, rice-cowpea (var: V-118) recorded the highest (60.8 Q/ha) along with net returns (₹ 22,855/ha) Indicating superiority of the system.

Table12. Productivity of the rice based cropping systems

Cropping system	Biomass produced (t/ha)	Rice equivalent yield (Q/ha)	Total net income (₹/ha)
Rice (Annanda) - Green gram (Pusa Baisakhi)	16.62	44.9	11,561
Rice-Blackgram (K-3)	16.57	44.6	11,360
Rice-Pigeonpea (ICPL-27)	18.01	51.3	16,002
Rice-Pigeonpea (S-31)	17.54	50.3	15,328
Rice-Cowpea (V-118)	17.56	60.8	22,855
Rice-Local *Alsondo*	20.70	51.9	16,190
Rice-Groundnut (DH-3-30)	18.15	55.6	18,531
Rice-Groundnut (DH-40)	17.36	53.9	17,233

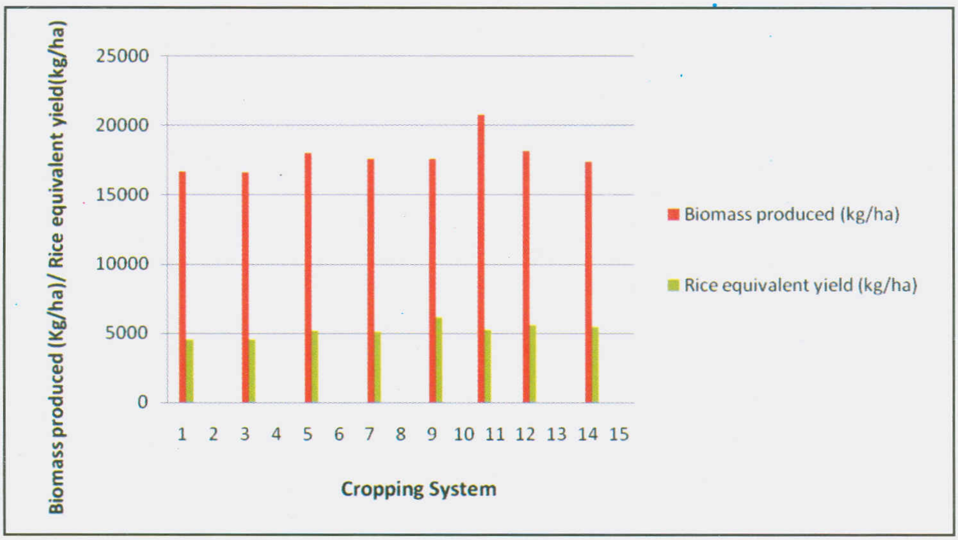

Fig 3. Productivity of the rice based cropping systems.

Evaluation of eco-friendly insecticides for the management of pulse pod borer, *Helicoverpa armigera*

Replicated field trials were conducted in the Institute to evaluate the efficiency of the bio pesticides. The trial were laid out on RBD with three replications. Red gram variety, DT-7 was used for the trial. Treatments (Table 13) were given when crop started flowering.

Among the treatments, Monocrotophos was very effective. Combination of *Bacillus thuringensis* (B.t) and neem insecticides have resulted in considerably higher yield when compared to the control and independent treatments.Though endosulfan treatment gave higher yield, statistically was at par with the combined treatments of B.t + neem insecticides.

Table 13. Effect of boi-pesticides in the management of pod borer *Helicoverpa armigera*

Sr No	Treatment	Mean yield of healthy pods (No/plot)	Mean yield of healthy grains (g)
1	Control	1563[b]	120[b]
2	Neem I	1641[b]	156[b]
3	Neem II	1720[b]	138[b]
4	Neem III	1468[b]	134[b]
5	*B. thuringiensis*	1919[ab]	159[ab]
6	Neem I + B.t	2130[ab]	167[ab]
7	Neem II + B.t	2322[ab]	187[ab]
8	Neem III + B.t	2296[ab]	173[ab]
9	Endosulfan	2334[ab]	198[ab]
10	Monocrotophos	2774[a]	271[a]

Values following the same alphabet are not significantly different DMRT (P=0.05)

4. Rice-Vegetable Sequential Cropping system

Rice-vegetable is a profitable sequential cropping system followed under protective irrigation after rice harvest during *rabi*-summer season. Traditional irrigation practices like dug out ponds utilizing the shallow ground water table is a common site where traditional vegetables like okra, cluster beans, chillies, brinjal, amaranthus, raddish, sweet potato, etc are cultivated.

Many high yielding vegetable types were introduced and evaluated and demonstrations were undertaken in both at the Institute as well as farmers field.

The productivity levels and the economics of the cultivation are as follows:

Table 14. Economics of vegetable cultivation in Goa

Crop	Mean yield (t/ha)	Cost of cultivation (₹/ha)	Income (₹/ha)	Net Profit (₹/ha)
Okra	6.0	28000	48000	20000
Cluster bean	5.4	32000	54000	22000
Chillies	3.0	29000	62000	33000
Brinjal	6.2	26000	62000	36000
Amaranthus	3.2	18000	32000	14000
Radish	6.4	18000	32000	14000

The economic analysis of rice-vegetable sequential cropping system revealed that rice- brinjal system is more profitable with higher productivity (6.2 t/ha with the local brinjal) and net returns (. 36,000/ha).

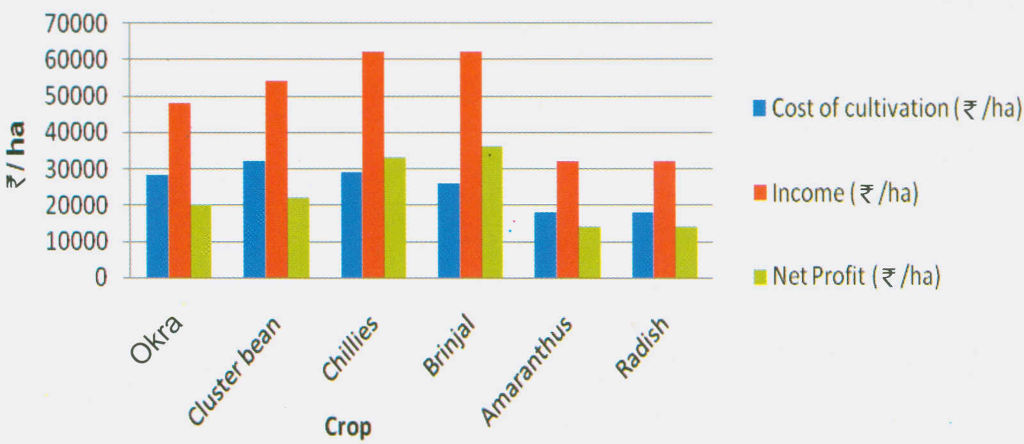

Fig 4. Rice-Vegetable sequential cropping system-ecnomics of cultivation

Plate 4. Vegetables in paddy fallows (under protective irrigation)

Sweet potato is an important crop of rice based cropping system in Goa. However the sweet potato weevil, *Cylas formicarius* (F) cause extensive damage to the crop. A field trial was therefore taken to find the suitable chemical measure for this pest . Also the female sex pheromone was tested in the field for the first time.

A trial involving 13 treatments including control was laid under the randomized block design in the farmers field. Insecticidal treatments were applied at planting by dipping the plant cuttings in Monocrotophos 36 S L (0.05% for 30 minutes before planting), spraying endosulfan 35 EC (0.07%) at 30 and 70 days after planting and drenching the soil with Endosulfan at 50 DAP. Though statistically non significant, the lowest "Damage Grade Index " of the crown (1.80) was obtained in the plots treated with Endosulfan at 30, 50 and 70DAP. The average infested tubers per plot was low in all the plots.

Preliminary observations with sex pheromone traps at four different locations gave good results.The average first day counts of adult ranged from 155.4 to 244.33 per trap, which came down to 81.33 to 46.67 per trap in about 12 days. The use of the female sex pheromone is therefore recommended for use in the field as component of IPM programme for weevil control.

A replicated field trial under the randomized block design was laid in the Institute farm wherein an insecticidal treatment schedule of 13 treatments including control was devised. Insecticide applications were made at four major stages of growth *viz.* (i) at planting by dipping plant cutting in monocrotophos 36 SL (0.05%) for 30 minutes before planting ii) spraying endosulfan 35 EC (0.07%) at 30 days after planting (DAP) and iii) drenching the soil with endosulfan (200ml/plant) at 50 and 70 DAP. Seventy five cuttings were planted per plot and all necessary agronomic practices were carried out to ensure good crop growth. At harvest the Damage Grade Index (DGI) due to weevil attack was calculated for the crown and tubers separately as per the scoring method recommended by the Central Tuber Crop Research Institute, Thiruvananthapuram.

At harvest the weight of the infested and uninfested tubers per plot was noted from which per cent infestation and per cent marketable tubers was calculated. Analysis of data showed that significantly highest percent marketable tubers (93.95%) were obtained when plots were treated at planting (dipping of cuttings in monocrotophos) and also sprayed and drenched with endosulfan at 30 and 50 DAP, respectively. Though statistically non significant, the least tuber infestation (6.05%) was also seen in plots receiving the above treatments at planting and at 30 + 50 DAP.

Statistically significant and lowest DGI value 0.63 was observed for plots treated at planting together with a spray at 30 DAP.This was followed by plots treated at planting together at 30 + 50 DAP (0.67). As regards the DGI for tubers, significantly superior and lowest score of 0.03 was recorded for plots receiving treatments at planting + 30 + 50 DAP.

In general, weevil infestation could be effectively controlled by dipping plant cuttings in Monocrotophos 36 SL (0.05%) for 30 minutes before planting together with a spray and soil drench (200ml/plant) of endosulfan 35 EC (0.07%) at 30 and 50DAP, respectively (Table 15).

Rice-brinjal cropping system

Rice-brinjal is a profitable rice based cropping system as was observed through experimental evidences. The local varieties of brinjal *viz.*, Agassaim and Taleigao have proven for their yield potential and are popular among the growers. In a cropping system trial, it was observed that rice-brinjal system gave the highest system productivity (11122 kg/ha) and the net returns (₹46,440/ha). However, the crop suffers from wilt and damping off diseases.

Management of bacterial wilt and damping off in brinjal by biological control

Many soil fungi and rhizosphere bacteria have been reported to be antagonistic against a wide range of soil borne diseases including damping off and wilt in several crops. *Trichoderma* spp are potent candidates of biological control of many plant diseases. *Pseudomonas fluorescens* is one of the plant growth promoting rhizobacteria (PGPR) that possess different modes of action *viz.* competition, induced systemic resistance, antibiosis and growth promotion in disease suppression. In this study, two species of *Trichoderma* and two isolates of *Psuedomonas fluorescens* were evaluated against *Pythium aphanidermatum*, a causal agent of damping off and *Ralstonia solanacearum*, a wilt pathogen in brinjal. Growth parameters were also recorded to study the effect of biocontrol agents on growth of brinjal plants.

Fungal and bacterial antagonists were mass multiplied and formulated using talc powder for easy application. Application of these biocontrol agents as seed and soil treatment reduced both pre and post-emergence damping off. Reduction of pre-emergence damping off ranged from 18.0 per cent to 42.0 per cent and post-emergence from 23.0 to 54.0 per cent. In case of wilt

Table 15. Chemical control of sweet potato weevil

Sr. No.	Treatments	Performance of parameters			
		Damage crown	Grade index	Tuber infestation(%)	Marketable tubers (%)
1	Dipping cuttings in monocrotophos 36 SL (0.05% for 30 minutes (D)	1.64 (2.23)	1.35 (1.33)	3.98 (15.75)	9.20 (84.25)
2	D+ spray endosulfan 35 EC (0.07%) At 30 DAP	1.03 (0.63)	0.96 (0.43)	4.09 (16.44)	9.16 (83.56)
3	D+30+soil drench with endosulfan at 70 DAP	1.07 (0.67)	0.73 (0.03)	2.55 (6.05)	9.71 (93.95)
4	D+30+50+soil drench with endosulfan at 70 DAP	1.08 (0.70)	0.86 (0.27)	2.57 (6.40)	9.70 (93.59)
5	30	1.14 (0.83)	1.01 (0.56)	3.34 (14.07)	0.28 (85.95)
6	30+50	1.14 (0.80	0.98 (0.47)	3.44 (11.56)	9.43 (88.44)
7	30+50+70	1.43 (1.60	0.83 (0.20)	3.20 (10.62)	9.47 (89.38)
8	D+50	1.01 (0.53)	0.81 (0.17)	3.50 (12.77)	9.36 (87.23)
9	50	1.12 (0.80)	0.93 (0.37)	3.65 (12.93)	9.36 (87.14)
10	50+70	1.12 (0.77)	0.84 (0.23)	3.29 (10.46)	9.49 (89.24)
11	D+70	1.52 (1.87)	1.14 (0.80)	3.72 (13.49)	9.33 (86.51)
12	70	1.37 (1.40)	0.92 (0.37)	3.98 (15.45)	9.23 (84.55)
13	Control	1.77 (2.63)	1.34 (1.33)	5.64 (32.06)	8.25 (67.94)
	SEm ±	0.10	0.07	--	0.20
	·CD(P=0.05)	0.29	0.20	NS	0.58

experiment, all antagonist treatments proved effective in reducing the wilt incidence and increasing the yield under field conditions. The growth parameters and vigour index recorded in nursery were high in *Psuedomonas fluorescens* treatments followed by *Trichoderma* treatment. Also application of *Trichoderma* spp. and *Psuedomonas fluorescens* reduced the population of *P. aphanidermatum* in soil after ten days of treatment.

Lowest population of the pathogen was observed after 20 days of treatment. These results showed that *Trichoderma* and *Psuedomonas fluorescens* could be used effectively for the management of damping off in nursery and wilt in the main field as both possess different modes of action for pathogen suppression and growth promotion. For wilt management in brinjal *Psuedomonas fluorescens* may be used as an inducer of systemic resistance in plant against the systemic pathogen.

Table 16. Effect of bio-control agents on wilt incidence and yield parameters

S. No.	Treatments	% infection		Cumulative mean	Yield (t ha^{-1})		Cumulative mean
		2001	2002		2001	2002	
1	Pf1	2.50 ± 0.72^{ab} (6.47)	19.26 ± 9.37^{ab} (24.22)	10.88	18.00 ± 1.25^{a}	20.09 ± 1.37^{cd}	19.05
2	Pf7	1.25 ± 0.63^{a} (3.24)	20.84 ± 5.73^{abc} (26.18)	11.05	19.58 ± 2.42^{a}	18.23 ± 0.93^{bc}	18.91
3	Tv1	5.00 ± 1.77^{abc} (8.93)	9.80 ± 1.53^{a} (18.08)	7.40	15.72 ± 1.66^{a}	17.96 ± 1.53^{bc}	16.84
4	Tv2	8.75 ± 0.63^{bc} (17.06)	31.60 ± 7.29^{bc} (33.66)	20.18	15.21 ± 1.61^{a}	16.47 ± 2.25^{ab}	15.84
5	Carbendazim	7.50 ± 1.25^{bc} (15.39)	25.81 ± 3.13^{bc} (30.40)	16.66	17.58 ± 0.28^{a}	21.63 ± 1.54^{d}	19.61
6	Control	10.00 ± 1.02^{c} (18.14)	35.29 ± 3.81^{c} (36.34)	22.65	14.98 ± 2.51^{a}	14.17 ± 0.47^{a}	14.58
	CD (P=0.05)	10.07	10.08	-	-	2.88	-

Values in the parentheses are arc sine transformed values; In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Management of bacterial wilt in brinjal by biological control

Incidence of bacterial wilt in brinjal is severe in the coastal regions of our country and no absolute control measure is available. Antagonistic biocontrol agents viz. *Psuedomonas fluorescens* and *Trichoderma viride* were evaluated under field conditions by seedling dip method to assess the wilt incidence and yield in a local cultivar of brinjal. Treatment with talc based formulation of *Psuedomonas fluorescens* and *T. viride* either alone or in combination reduced bacterial wilt incidence significantly during 2003 and 2004. Besides, the biocontrol agents increased the fruit and fruit weight significantly. Maximum yield was recorded in *Psuedomonas fluorescens* (Pf1+Pf7) treatment during 2003 and *Trichoderma viride* and *Psuedomonas fluorescens* (Tv1+Pf7) treatment during 2004. Hence, growth promoting biocontrol agents could be incorporated in the future brinjal wilt management programmes.

Table 17. Effect of seedling dip treatment with biocontrol agents on brinjal wilt incidence, yield and fruit weight

Treatments*	Wilt (%)		Yield (t/ha)		Fruit wt (g)	
	2003	2004	2003	2004	2003	2004
Tv1	53.13	9.38	8.73	11.16	370	136
Pf1	41.67	11.46	11.43	10.89	304	160
Pf7	42.71	14.58	9.87	8.93	441	141
Pf1 + Pf7	41.62	19.79	12.30	11.44	427	158
Tv1 + Pf1	32.30	20.83	10.57	12.27	491	158
Tv1 + Pf7	53.13	14.58	9.50	12.58	408	151
Copper oxychloride	51.05	21.88	9.78	10.67	507	170
Streptomycin	63.54	20.83	7.47	8.02	422	140
Control	86.46	28.13	6.37	7.78	204	114
CD ($P \leq 0.05$)	15.25	5.59	NS	2.89	NS	29

* Tv1 = *Trichoderma viride*, Pf1 and Pf7 = *Pseudomonas fluorescens;* Values were arc sine transformed before analysis; NS- Non-significant.

Field evaluation of talc based antagonistic bacteria on the incidence of eggplant wilt and yield

Forty eight endophytic bacteria and 101 rhizobacteria screened for their antibacterial activity against *Ralstonia solanacearum*, causal agents of brinjal wilt. Among 22 effective isolates, 18 were *Pseudomonas* spp. forming three groups based in biochemical characterization of 75 per cent similarity. Talc formulation of the antagonistic bacteria and 48 hrs. old grown bacterial cells were evaluated in the green house condition for the suppression of brinjal wilt. Talc formulation of two species of *Pseudomonas* (RBh41 and RBh42) completely suppressed the incidence of wilt up to 36 days of inoculation. Treatment with bacterial cells of *Psuedomonas mallei* (RBG4, ET17) and one *Bacillus* spp. (RCh6) reduced wilt incidence of 83 per cent compared to control. *Pseudomonas* strains (RBh41, RBh42, RBG4, ET17) improved shoot and root length when brinjal seeds were treated. Talc formulations of seventeen isolates were prepared and used for treating the nursery and seedlings during transplanting. Bio control efficiency of 100% was recorded in *Bacillus* spp (RP7) treatment and 80% was recorded by EB69, RCh6 and RBG4 treatments. Yield increase of over 80% was recorded in RP6 and EB69 treatments followed by RBG4 treatment (>75%). EB69, RBG4 (*Pseudomonas* spp.) and RCh6, RP7 (*Bacillus* spp.) reduced wilt over 80 per cent and increased the yield (30 to 80%) and hence these isolates could be considered for developing potential biocontrol agents with plant growth promoting characteristics for management of *Rhizoctonia solanacearum* in brinjal.

IV. Identification of profitable rice based cropping systems

Field experiments were conducted for three crop seasons during 1999-2002 at ICAR Research Complex for Goa, Old Goa. The soil of the experimental site was sandy loam, acidic in reaction (pH-5.99), with no salinity (EC-0.072 dSm^{-1}) and good in organic matter content (0.90 % OC), having moderate levels of available N (292 kg/ha), P_2O_5 (37.9 kg/ha) and K_2O (264 kg/ha).

The experiment was conducted in a split-plot design with three replications. The manurial resources from the rice based cropping systems and allied agro-enterprises of dairy, poultry and mushroom production *viz.* farm yard manure, poultry manure, paddy straw with mushroom spent substrate (in 2:1 ratio) along with a control (no manure) formed the main plot treatments. Rice (variety Jyothi) based cropping systems suited to the location *viz.* rice-groundnut (variety DH-3-30), rice- cowpea (variety V-118), rice- brinjal (variety local Agassaim), rice-sunnhemp with rice- fallow system (to assess the economic loss on fallowing which is an important problem of the region) as control constituted the sub plot treatments. All the crop residues were incorporated *in situ* after the crop harvest.

Recommended package of practices were followed for rice and rice based cropping systems. All the crops were grown under residual moisture except brinjal which was raised under protective irrigation as per the local practice. No effective rain was received during the *rabi* season.

For comparison of different cropping systems, rice grain equivalent yield was worked out by converting the economic yield of groundnut, cowpea, brinjal and sunnhemp on the basis of marketable price ratio for each crop and rice and expressed in kg ha^{-1}.

$$\text{Rice grain equivalent (kg)} = \frac{\text{Productivity of component (kg)} \times \text{Cost of component (₹ unit}^{1}\text{)}}{\text{Cost of rice (₹ kg}^{1}\text{)}}$$

The productivity of the different rice based cropping systems in terms of rice grain equivalent yield is presented in Table. Among the cropping systems rice-brinjal system yielded the highest productivity in terms of rice grain equivalent yield (11,122 kg/ha) and was followed by rice-cowpea system (7,661 kg./ha). The higher productivity was due to the higher yield obtained with brinjal having bigger sized fruits (average weight of more than 250 g / fruit) and more number of fruits per plant. Similarly, early duration of the cowpea variety V-118 with compact branching and synchronous maturity coupled with better root establishment in the early stages of the crop resulted in the higher productivity. Among the recycled manures, paddy straw with mushroom spent substrate in 2:1 ratio found to be better (7276 kg./ha) over others.

Rotation with groundnut has increased the grain yield of subsequent rice by 5 q/ha (5061 kg/ha) over keeping the land fallow (4531 kg/ha) while brinjal rotation was next best in order (4977 kg/ha).This may be attributed not only due to the crop rotation effect of legume but also due to turning in of about 2.4 tonnes of haulms having narrow C:N ratio after harvest. However, there was no appreciable influence of cropping systems on the straw yield of subsequent rice. Thus, rice-brinjal system seem to be a better option both from the productivity and sustainability point of view.

Table 18. Grain and straw yield of rice as influenced by cropping systems and recycled manurial resources (pooled mean of two years)

Cropping system/Manurial resources	Grain yield (kg/ha)					Straw yield (kg/ha)				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
Rice-Fallow	4459	4241	4300	5125	4531	4888	5018	4454	5233	4898
Rice Groundnut	4364	5125	5459	5296	5061	4801	4884	4871	4615	4795
Rice-Cowpea	4901	4718	4966	4220	4701	4584	4554	480	3957	4474
Rice-Brinjal	5127	4672	4652	5456	4977	5327	3904	4526	5141	4725
Rice Sunnhemp	4196	5510	4136	4783	4656	4266	5073	4334	3991	4416
Mean	4609	4853	4703	4976		4775	4687	4597	4587	

M_0 - No recycled manure + Recommended NPK

M_1 - Recycled FYM + Recommended NPK

M_2 - Recycled poultry manure + Recommended NPK

M_3 - Recycled mushroom spent substrate + Recycled paddy straw + Recommended NPK

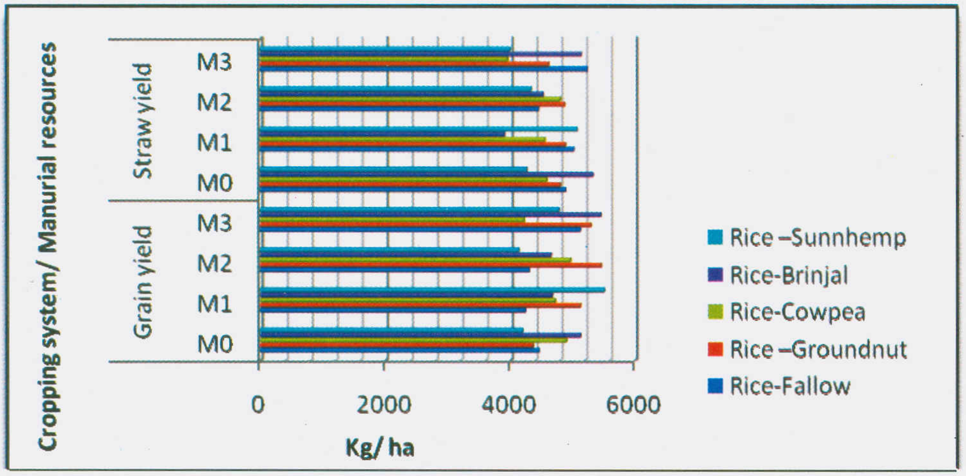

Fig 5. Grain and straw yield of rice as influenced by cropping systems and recycled manurial resources

Productivity of rice based cropping systems

The economic yield of different rice based crops as influenced by recycled manurial resources during both the years of experimentation is presented in Table 19.

Groundnut yield was positively influenced by the use of poultry manure (12.21 q/ha) followed by FYM (10.77 q/ha). However, cowpea seed yield was much higher (11.68 q/ha) with recycled paddy straw along with mushroom spent substrate as compared to either poultry manure (8.42 q/ha) or FYM (8.10 q/ha) . Similarly, highest brinjal yield (14.19 q/ha) was recorded with paddy straw along with mushroom spent substrate. The treatment recorded 12.7 per cent higher productivity over no manure. The higher productivity may be attributed to the more number of fruits per plant and average fruit weight in brinjal, in contrast to other manures.

Table 19. Recycled manurial resources in influencing economic yield of rice based crops

Manurial resource/rice based crop	M_0	M_1	M_2	M_3	Overall mean
Groundnut pods (q/ha)	8.62	10.77	12.21	9.37	10.24
Cowpea seeds (q/ha)	7.15	8.10	8.42	11.68	8.84
Brinjal fruits (t/ha)	12.78	12.53	10.94	14.99	12.81
Sunnhemp biomass (t/ha)	12.10	11.19	11.91	11.85	11.76

Rice grain equivalent yield

The equivalent yield differed significantly both due to manures and cropping systems during second year. The interaction effects, however, were not significant.

Significantly higher rice grain equivalent yield was observed with paddy straw and mushroom spent substrate as compared to others. The treatment recorded higher productivity (7276 kg/ha) of rice based crops. This may be due to enhanced uptake of N, K, Ca, Mg ,Fe, and Zn by the crop plants.

Among the cropping systems, rice-brinjal system (under protective irrigated conditions) yielded significantly higher rice grain equivalent yield (13686 kg/ha) during first year. A similar trend was also observed during the second year. The increase was 158, 70, 45 and 123 per cent more over rice-fallow, rice-groundnut, rice-cowpea and rice-sunnhemp cropping systems, respectively, thus indicating the suitability of the cropping systems to the region . Further, better price for the produce resulted in higher rice grain equivalent yield for rice-brinjal system as compared to other systems. Further, it was also observed that growing of either groundnut (4713 kg/ha) or brinjal (4655 kg/ha) after rice was found to enhance the grain yield of subsequent rice crop as compared to others among the cropping systems tried.

Table 20. Rice grain equivalent yield (kg ha^{-1}) in different rice based cropping systems

Cropping systems/Recycled manures	1999-2000					2000-2001				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
Rice-fallow	4202	4302	4203	4458	4291	4230	4039	4134	4917	4330
Rice-Groundnut	5859	6371	6546	6252	6257	5662	7042	7703	7024	6858
Rice-Cowpea	7427	7176	7005	8604	7553	7483	7992	9286	6317	7770
Rice-Brinjal	13649	13564	12281	15249	13686	8716	7828	7734	9950	8557
Rice-Sunnhemp	5153	5201	5244	5408	5252	4295	5839	4118	4684	4734
Mean	7258	7323	7056	7994	8007	6077	6548	6595	6578	6450

C.D (P=0.05)		
Main Plot	584.9	NS
Sub Plot	289.0	511.7
Interaction	NS	NS

M_0 - No recycled manure + Recommended NPK

M_1 - Recycled FYM + Recommended NPK

M_2 - Recycled poultry manure + Recommended NPK

M_3 - Recycled mushroom spent substrate + Recycled paddy straw + Recommended NPK

Similarly, early duration of the cowpea variety V-118 with compact branching and synchronous maturity coupled with better root establishment in the early stages of the crop could able to extract more moisture and result in higher productivity.

Profitability of the cropping system

The economic analysis in terms of gross returns, cost of production and net returns as observed in different treatments of rice based cropping systems is presented in Table 21.

Pooled mean gross returns differed significantly among the cropping systems tried with rice-brinjal system recording significantly higher gross returns (₹ 87,640/ha). Rice-cowpea system was next best in order (₹ 64,390/ha). The lowest gross returns were noticed when no crop sequence was followed after rice (₹ 34,615/ha). The pooled mean gross returns obtained under different recycled manures did not differ significantly among themselves. However, recycled paddy straw along with mushroom spent substrate recorded relatively higher gross returns (₹ 64,330/ha) as compared to others, while the least gross returns were observed when no manure was recycled (₹ 58,130/ha).

Table 21 . Pooled mean economic analysis of rice based cropping systems

Cropping system/ recycled manurial resources	Economics (Rs/ha)			
	Gross returns	Cost of production	Net returns	Per day net return
Recycled manure				
M_0	53325	22490	30830	142.3
M_1	55025	25490	29532	136.8
M_2	55305	23890	31410	144.9
M_3	60770	24490	36280	164.7
F Test	**NS**	**NS**	**NS**	**NS**
Cropping system				
CS_0	34615	15230	19385	152.0
CS_1	54590	24800	29790	114.1
CS_2	64390	21810	42570	195.3
CS_3	87640	41145	46440	163.0
CS_4	39300	17410	21890	110.5
F Test	**	**	**	**
S.Em ±	**2600**	**653**	**2600**	**11.1**
C.D (P = 0.05)	**7477**	**1880**	**7477**	**31.9**
Interaction	**NS**	**NS**	**NS**	**NS**

M_0 - No recycled manure + Recommended NPK
M_1 - Recycled FYM + Recommended NPK
M_2 - Recycled poultry manure + Recommended NPK
M_3 - Recycled mushroom spent substrate + Recycled paddy straw + Recommended NPK

CS_0 → Rice - Fallow
CS_1 → Rice - Groundnut
CS_2 → Rice - Cowpea
CS_3 → Rice - Brinjal
CS_4 → Rice - Sunnhemp

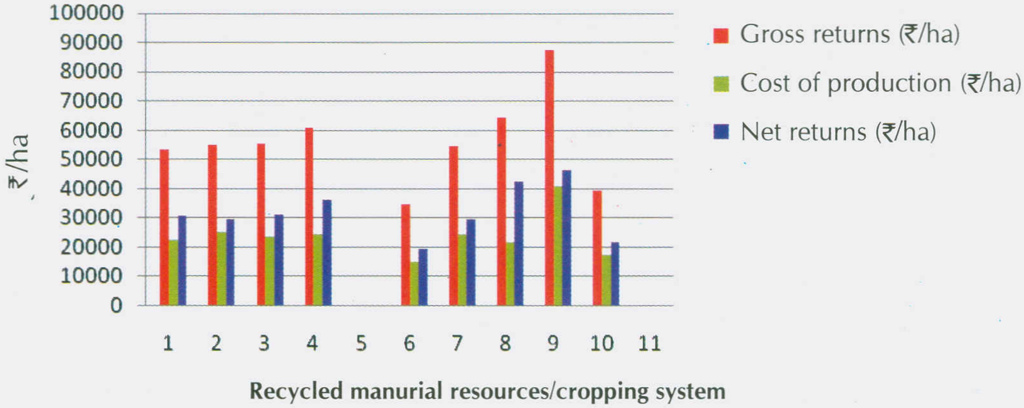

Fig 6. Pooled mean economic analysis of rice based cropping systems

The cropping systems differed significantly in terms of cost of production among themselves. Cost of production of rice-brinjal system was significantly higher (₹ 41,145/ha) as compared to rest of the treatments. Cost of production of rice-groundnut system (₹ 24,800/ha) was significantly more than rice-cowpea system (₹ 21,810/ha). Similarly rice-cowpea system had a significantly higher cost of production (₹ 21,810/ha) than rice-sunnhemp system (₹ 17,410/ha) and the cost of production of rice-sunnhemp system (₹ 17,410/ha) was significantly different from rice-fallow system (₹ 15,230/ha). Among the recycled manurial treatments, cost of production was significantly higher with recycled FYM (₹ 25,490/ha) and recycled paddy straw with mushroom spent substrate (₹ 24,490/ha) in comparison to no recycled manure (₹ 22,490/ha). However, the cost of production with recycled FYM and paddy straw with mushroom waste as well as the latter and the recycled poultry manure treatments were found at par with each other although recycled FYM treatment differed significantly with recycled poultry manure in terms of its cost.

The net returns differed significantly among the cropping systems (Table 21). Significantly higher mean net returns were obtained with rice-brinjal cropping system (₹ 46,440/ha). This system although, was at par with rice-cowpea system (₹ 42,570/ha), differed significantly with rest of the cropping systems. Similarly, rice-cowpea system recorded significantly higher net returns per unit area as compared to either rice-groundnut system (₹ 29,790 mean net returns/ha) or rice-sunnhemp system (₹ 21,890/mean net returns/ha). These systems have recorded 139.6 and 119.6 per cent higher mean net returns over the rice-fallow system indicating their superiority in monetary gains. Higher productivity in both brinjal and cowpea coupled with good market demand for the produce have led to higher returns from these systems. Although net returns were not significantly influenced by the recycled manurial resources, relatively higher net returns (₹ 36,280/ha) were observed with recycled paddy straw along with mushroom spent substrate. Recycling of poultry manure was next best in terms of mean net returns (₹ 31,410/ha). The interaction effect of net returns in recycled manures and cropping systems, however, was not significant.

Per day net returns differed significantly among the cropping systems. Highest returns (₹ 195/day) was obtained with rice-cowpea system which differed significantly with rest of the treatments mainly due to the shorter duration of the cowpea variety used. Adopting rice-brinjal system was next best (₹ 163/day) in terms of returns/day which also differed significantly. However rice-sunnhemp system and rice-groundnut system gave lower per day returns (₹ 111 and 114/, respectively). The net returns per day did not differ significantly among the recycled manurial resources. However, with recycling of paddy straw along with mushroom spent substrate, higher net returns (₹ 165/day) were obtained. Recycling of poultry manure was next best (₹ 145/day) while recycling of FYM was not that economical (₹ 137/day).

Transfer of technology

Seven groundnut varieties were introduced in the State and their superiority was demonstrated over the traditionally cultivated groundnut under the residual moisture situation in rice fallows. The work included analysis of the traditional system with problems and to suggest technological interventions of not only relating to the supply of critical input like seed in time but also incorporated other inputs like phosphorous management, bio fertilizer usage and other inputs. More importantly, the most opportune time for sowing *rabi* groundnut to derive maximum benefit from the residual moisture.

Table 22. Pooled data on FLD on groundnut 2002-03 to 2007-08

Year	Area (ha)	Beneficiaries Males	Beneficiaries Female	Total	No. of villages	% women Involvement
2002-03	9.80	29	8	19	9	21.6
2002-04	9.40	44	18	62	8	29.0
2004-05	10.00	49	15	64	2	23.4
2005-06	15.50	61	8	111	4	25.0
2006-07	1.00	17	4	2	3	24.0
2007-08	2.00	13	2	10	3	13.3
Total	47.70	213	55	268	29	22.7

The topography of the State has hilly or *morod* lands like for instance in Dhargal village of Pernem taluka where traditional crops like finger millets, chillies, and a few cucurbits are grown many farmers are growing groundnut. The soils are deep with very good drainage and ideally suited for *kharif* groundnut. However, the total area under groundnut cultivation is less compared to the *rabi,* where this crop is taken under residual soil moisture in rice fallows. The *kharif* areas serve as potential sites for groundnut seed multiplication which then goes into the *rabi* season. This helps in maintaining the seed chain. Only traditional old variety JL-24 or a mixed seed was being cultivated by majority of farmers. The project was initiated in Dhargal village covering 11 ha during *kharif* season and after proper selection of farmer's through the help of local village Panchayat, quality seed of TAG-24 and Dh-86 was tested under OFT and later shifted to FLD.


Plate 5.
Two new varieties viz; Dh-86 (left) and TAG-24(right) being tested under OFT during *kharif* at Pernem


Plate 6.
Sarpanch of Dhargal village visiting FLD and Dr S.N Nigam (ICRISAT) visiting FLD in *kharif*

Similarly, other villages like Tamboxem, Torxem, Dadachiwadi, Devulwada and Chikulem in Dhargal were identified and selected to conduct the FLD in groundnut during *kharif* 2005. The seed village concept was initiated with active support of the Zonal Agricultural officer of Pernem taluka and the Sarpanch of Dhargal village. The FLD results gave encouraging results with TAG-24 and DH-86 (1.86 t/ha 1.69 t/ha, respectively) and both surpassed the local check JL-24(1.17 t/ha). The seed material out of this demonstrations was exchanged among the farmers in Virnoda and Mahakhazan locations in Dhargal village during the *rabi* season. Besides over three tonnes of seed of these two varieties were procured by the State department during the season for further popularization in area under rice fallows during *rabi*.

Plate 7. The *kharif* seed (TAG-24) being multiplied under KVK supervision in Dhargal village

The Mahakhazan belt is typical rice based farming system with Colvale river flowing adjacent to it. The water table is high and is an ideal site for taking up groundnut seed programme as is being presently done. Part of these valuable seed is again taken back through seed exchange to *kharif* areas within the taluka and the cycle is maintained. The village is a potential seed village which caters to a large extent the seed replacement.

Distress sale of produce was a regular feature by the farmers with their traditional varieties. The awareness created through regular interventions by educating the beneficiaries regarding maintaining seed purity, rouging of off types as well as proper post harvest techniques and grading and the economic advantage thereof, growing the crop for seed purpose rather than oil purpose has resulted in horizontal spread of the technology not only in terms of replacement of traditional variety but also the agro-techniques to get higher yields under residual moisture situations as can be seen from the present coverage of TAG-24 which occupies more than 90 percent of the area in the State.


Plate 8. Seed multiplication efforts through successful FLD and its quality being ensured through inspection

Plate 9. View of TAG-24 variety at Dhargal village


Plate 10. Bumper harvest through groundnut technology transfer at Dhargal and Sangolda villages serving as seed plots

Among these many have created impact in the State like Shri Sripad Palekar, Shri Prakash Bali, Shri Dadu Ambre to mention a few around the Sangolda and Porvorim area of Bardez taluka and Shri Jaykumar Salgaokar and others in Dhargal village of Pernem taluka.

Plate 11. View of Frontline demonstation withTAG-24 at Dhargal (L) & visit of Dr Solanki alongwith Dr Jamble (KKV,Dapoli) at site(R)

In fact, these areas which have been exposed to the groundnut technology represent the potential groundnut seed source to the local Agriculture department for the varieties introduced. The areas and the farmers in the area still continue to take the groundnut crop even after the discontinuation of the FLD project which clearly indicates viability of the technology adopted by these farmers. During the period, the following five groundnut varieties were demonstrated in the State through the FLD'

Table 23. Pooled results on the performance of groundnut varieties under FLD (t/ha) 2002-03 to 2007-08

Year	Jl-24	TG-37/A	TAG-24	GPBD-4	Dh-86	Check	Mean
2002-03	***	**	2.25	***	**	1.27	2.25
2002-04	2.08	**	2.17	1.81	1.79	1.60	1.96
2004-05	1.53	**	2.17	1.80	1.68	1.39	1.83
2005-06	1.47	**	1.94	**	1.48	1.47	1.59
2006-07	**	**	2.12	1.80	**	1.59	1.84
2007-08	1.28	2.16	2.15	**	**	1.38	2.05
Mean	**1.59**	**2.16**	**2.13**	**1.80**	**1.65**	**1.45**	1.92

The table clearly indicates the superiority of improved technology in groundnut cultivation over the traditional farmers practice. The pooled data over these years suggests that the groundnut variety TAG-24 has an edge over other varieties tried under these demonstrations.

The demonstration results indicate that the highest demonstration yield of 2.8 t/ha can be achieved under residual soil moisture situations if one or two life saving irrigations are given at peak flowering and early pod formation stages of the crop. The above data from Frontline demonstrations on groundnut also suggests that the percentage increase of TAG-24 other varieties has been impressive and has created an impact and resulted in higher yield than the farmer's practice and the traditional variety. The percent increase in yield of the demonstrated varieties over the farmer's practice and variety resulted in 9.53 per cent in JL-24, 13.88 per cent in Dh-86, 24.7 per cent in GPBD-4, 47.16 per cent in TAG-24 and 48.89 per cent in TG37-A resulting in superiority of technology demonstrated under the Front-line demonstrations.

Confectionery Groundnut

Nature has designed only a few food stuffs that are so rich in important nutrients as the kernels of groundnut. They contain more protein than meat, and two and half times that in eggs and far more than any other vegetable food except soybean. Thus, groundnut is one of the cheapest sources of quality protein. With 20-26 per cent protein, 40-48 per cent fat, about 3 per cent fibre and high calcium, thiamine and niacin contents, it has all the potential to be used as highly economical food supplement to fight malnutrition that occurs due to deficiencies of these nutrients in the cereal diet like wheat and rice. Thus, groundnut is a nature's gift to man and specially so to children, pregnant and nursing women and the poor and rightly called the poor man's "Badam". The nutritive virtues of groundnut have attracted the attention of National Aeronautics and Space Administration of the U.S.A. who have identified it as possible food for advance life support system for extended space missions. Inshell roasted groundnuts sold by hawkers around public places, cinema halls, theaters, fairs, exhibitions, shopping plazas, etc.; are one of the most popular snack foods in India. Since groundnut is highly satiating, it checks the appetite and is hence popular among health conscious people. Confectionery groundnuts on the other hand, are low fat and high protein commodity which is classified as food item rather than the contemporary oilseed classification.

Plate 12. A view of confectionery groundnut varietal trials conducted at Institute farm and visited by Hon'ble M. P of Goa Shri Shripad Naik

One of major contributions under the Project has been the introduction, evaluation and recommendation of high value confectionery groundnut in the State. The research project that was carried out between 2002-03 to 2005-06 in collaboration with ICRISAT, Hyderabad led to the identification of varieties which were later field tested under OFT both under raifed as well under residual soil moisture conditions at Parra, Dhargal, Saligao villages in North Goa.

While the staple cereal crop rice in the region is being sown by the majority of farmers in the upland, midland and lowland ecosystems a unique experiment based on the success of research findings at ICAR Complex was being field tested at three locations in North Goa, to confirm the findings at farmer's level, so that the recommendations of this experiment could be passed on to other farmers. The dedication and urge to seek technological innovations has been a desired trait in Fr. Inacio Almeida, a missionary by his own right and beneficiary of many of the innovative technologies propagated in the past two decades since the Lab to Land Programme was launched in the country. The present initiative was taken at a remote village Bhironde in Valpoi taluaka and on the farm.

Plate 13. Confectionary groundnut varieties being demonstrated at Bhironde farm by Fr. Inacio Almeida

A successful FLD was conducted during *Kharif* 2008 at Bhironde village in Valpoi taluka of North Goa District with Confectionery groundnut "Asha" and "TPG-41" by a progressive farmer Fr. Inacio Almeida. More than 600 kg seed material was produced out of this effort on barren land. The seed is distributed to farmers of the area for taking up further. multiplication during the *rabi* season under protective irrigation

V. Rice based farming systems

Systems that are less dependent on external inputs have better prospects for sustainability, as long as they can meet the needs of producers and consumers. The basic principle of sustainability is to meet the economic, ecological and social needs of the society, without impairing the opportunities of development of future generations. Sustainable farming system require that crop yields are stable through the maintenance of soil fertility and the balance of the nutrients in the system.

Soil organic carbon (SOC) changes can provide valuable information regarding management impacts on carbon sequestration and sustainability. Increase in soil C levels require sustained periods of balanced fertilizers and residue retention. Intensive cropping with no return of crop residues and other organic inputs to the soil result in the loss of soil organic matter and nutrient supply and is assumed to be non-sustainable (Manjunath *et al.*, 2009$_a$).

Field experiments were conducted in a split-plot design with three replications. The manurial resources from the rice based cropping systems and allied agro-enterprises of dairy, poultry and mushroom production *viz.* farm yard manure, poultry manure, paddy straw with mushroom spent substrate (in 2:1 ratio) along with a control (no manure) formed the main plot treatments. Rice (variety Jyothi) based cropping systems suited to the location *viz.* rice-groundnut (variety DH-3-30), rice- cowpea (variety V-118), rice- brinjal (variety local Agassaim), rice-sunnhemp with rice- fallow system (to assess the economic loss on fallowing which is an important present problem of the region) as control constituted the sub treatments. The manures were applied to rice crop at planting and the quantity depended on the availability of the resource within the system. All the crop residues were incorporated *in situ* after the crop harvest. The recommended dose of fertilisers were applied to the crops. For comparison of different cropping systems, rice grain equivalent yield was worked out by converting the economic yield of groundnut, cowpea, brinjal and sunnhemp on the basis of marketable price ratio for each crop and rice and expressed in kg ha^{-1}.

$$\text{Rice grain equivalent (kg)} = \frac{\text{Productivity of component (kg)} \times \text{Cost of component (₹ unit}^{1})}{\text{Cost of rice (₹ kg}^{1})}$$

Mushroom production was integrated with the crop components using the paddy straw, which was available within the system. Broken rice and rice bran formed the ingredients of a formulated feed for the integrated poultry unit. The returns were calculated based on the prevailing market price for inputs and produces during the period.

Soil samples were collected before the start of the experiment and after harvest of each crop. Pre-experimental composite sample was collected at 30 cm depth and analysed for chemical properties. Post harvest samples were collected upto 30 cm depth, dried under shade and analysed for pH, EC, O.C, available N, P, K, Ca, Mg, S, Fe, Mn, Cu and Zn as per the standard procedures (Piper, 1966 ; Jackson, 1967).

The sustainability was assessed quantitatively through Sustainable Yield Index (SYI) which denotes the minimum guaranteed yield as a percent to the maximum observed yield with high probability as per Singh *et al;* (1990) given by

$$SYI = \frac{Y - \sigma}{Y_{max}}$$

Where Y is the estimated average yield of a treatment over years, σ is its estimated standard deviation and Y_{max} is the observed maximum yield in the experiment. Sankar and Reddy (2005) inferred that highly sustainable practices are with a sustainability index of 0.96. Further, SYI is an approach to evaluate the minimum yield likely to be achieved in relation to changes in soil organic carbon and available NPK status of soil.

1. Performance of integrated enterprises

The average production of mushroom was 493 kg /1000 bags of one kg capacity (on wet weight basis). The production was spread over the year with storing of paddy straw obtained from the system.

The requirement of feed for poultry formulated using the ingredients obtained from rice production system was nearly the same (2.35 kg/bird) as compared to the control feed (2.47 kg/bird).

Plate 14. Field trial on rice based systems

Plate 15. Integrated Oyster mushroom and broiler poultry production

Table 24. Performance of broiler chicks reared with formulated feed

Variables	Formulated feed	Control feed
Total feed requirement for 72 birds (kg)	169.0	177.8
Feed consumption (g / bird)	2350	2470
Feed conversion (g feed /g gain)	2.14	2.17
Livability	94.4	91.7
Av. weight of birds at 42 days (g)	1207	1186
Weight gain (g / bird)	1161	1140
Dressing per cent	77.3	76.2
Poultry waste production (g / bird)	667	673
Total poultry manure production including coir waste litter for 72 birds (kg)	140.4	140.9
Feed cost (Rs/kg)	6.36	8.10

The feed conversion efficiency in terms of feed required to produce a unit gain in weight was better with formulated feed (2.14 g feed/g gain) as compared to the control feed. The average weight of the birds at the age of marketing was slightly higher with formulated feed (1.21 kg), with better liveability (94.4%) and dressing per cent (77.3%) over the control feed. Although poultry manure production was higher with the control feed (673 g/bird), the overall feed efficiency was better with formulated feed. Further, there was a substantial reduction in the feed cost to ₹ 6.36 / kg of formulated as against ₹ 8.10/kg of control feed. The better performance of integrated mushroom and poultry units indicated that these enterprises are complimentary with rice production. The cost of maintenance of mushroom was cheaper (only 38.8 % of poultry), owing to the cheaper raw material for its cultivation.

2. Productivity of the integrated systems

The contribution of crops towards the system productivity ranged from 33 to 52 per cent, while poultry and mushroom contributed 28 to 39 per cent and 20 to 28 per cent, respectively.

The highest system productivity of 21,487 kg/ha/year of rice grain equivalent yield was recorded with rice-brinjal system integrated with mushroom and poultry production. This was followed by rice-cowpea (18,027 kg/ha/year) and rice-groundnut system (16922 kg/ha/year) integrated with mushroom and poultry production. Rice-brinjal with mushroom and poultry system recorded nearly 400 per cent more productivity, of which 240 per cent was

Table 25. Productivity of integrated farming systems

Farming system	Component productivity (kg ha^{-1})			Rice grain equivalent yield (kg ha^{-1})
	Crop	Poultry	Mushroom	
Rice cropping alone	4311	-	-	4311
Rice - Groundnut + Mushroom + Poultry	6557(39)*	6060(36)	4305(25)	16922
Rice - Cowpea + Mushroom + Poultry	7662(43)	6060(34)	4305(23)	18027
Rice - Brinjal + Mushroom + Poultry	11122(52)	6060(28)	4305(20)	21487
Rice - Sunnhemp + Mushroom + Poultry	4993(33)	6060(39)	4305(28)	15358

* Figures in parenthesis indicate per cent contribution to the total system productivity

contributed by allied enterprises *viz.* mushroom (100%) and poultry (140%). Similarly, rice-cowpea sequence cropping integrated with mushroom and poultry gave 318 per cent more productivity over rice alone.

Poultry and mushroom production when maintained with recycled by-products of rice production system such as paddy straw, rice bran and broken rice, the dependence and cost incurred on externally purchased inputs was greatly reduced. A better market for the products viz. mushroom, poultry etc. resulted in substantial benefits to the system. Thus, integration of poultry and mushroom production with recycling of by-products obtained from rice system enhanced the productivity of marginal rice lands substantially.

3. Economic analysis of the system

The pooled economic analysis of the system revealed that rice-brinjal system integrated with mushroom and poultry was highly economical with the highest net returns (₹ 77,305/ha). The system also recorded a moderate B:C ratio (0.93) with better per day net return (₹ 204/day). Rice-cowpea system integrated with mushroom and poultry was next best in terms of net returns (₹ 73,430/ha). The system with a lesser cost of production (₹ 63,510/ha) had a better benefit-cost ratio (1.16) with highest per day net return (₹ 238/day). However, rice cropping alone was the least yielding both gross returns (₹ 34,610/ha) and net returns wise (₹ 19,205/ha). Although the system had lower cost of production (₹ 15,405/ha), resulted in higher benefit : cost ratio. The net return per day was very poor (₹ 150).

Pooled mean analysis of the farming system study indicated that inclusion of mushroom and poultry enterprises incurred an additional cost of ₹ 41,700/ha mainly for the poultry feed and mushroom spawn. The cost of formulated feed prepared on the farm using the ingredients of rice production system, was cheaper by ₹ 1.75/kg (21.5% less). Between poultry and mushroom, the cost of maintenance of the latter is much cheaper (only 38.8% of poultry) owing to the cheaper raw material (paddy straw) for its cultivation.

Table 26. Economic analysis of rice based integrated farming system (pooled over three years)

Farming system	Gross return (₹ ha^{-1})	Cost of production (₹ ha^{-1})	Net return (₹ ha^{-1})	B : C ratio	Per day net return (₹ ha^{-1})
Rice cropping alone	34610	15405	19205	1.25	150
Rice - Groundnut + Mushroom + Poultry	127140	66490	60650	0.91	173
Rice - Cowpea + Mushroom + Poultry	136940	63510	73430	1.16	238
Rice - Brinjal + Mushroom + Poultry	160195	82890	77305	0.93	204
Rice - Sunnhemp + Mushroom + Poultry	111850	59100	52750	0.89	183

Thus, the results of the present study on selection of profitable cropping systems and their integration with suitable enterprises and recycling of wastes have clearly brought out the possibility of linking rice production with different related components for increased profitability.

4. Employment generation

The data on employment potential showed that rice-brinjal system integrated with mushroom and poultry is labour intensive (392 mandays/ha) involving sufficient manpower requirement particularly the women labour force which was almost three times of men labour requirement. Rice-groundnut integrated system was also labour intensive involving 350 man days of work per hectare. The ratio of women labour force requirement was nearly five times of men suggesting most of the activities are women labour oriented.

The present investigation revealed that adoption of an intensive cropping system like rice-brinjal could bring in additional employment opportunities to the tune of 118 mandays/ha over monocropping of rice (101% more). Thus, the family labour got an additional employment on their own farm, that too in the off season which could earn exactly double the wages (₹ 15,440 /ha) for labour employment compared to growing of rice alone (₹ 7,720/ha).

Further, when these intensive cropping systems are integrated with labour intensive enterprises like poultry and mushroom, an additional 164 mandays of employment could be expected. Thus, the total labour employment opportunities were enhanced three and half times within the same farm. Rice-cowpea + mushroom + poultry and rice-groundnut + mushroom + poultry farming systems are also equally good in enhancing the manpower absorption capabilities on the farm which recorded 213.6 and 218.2 per cent more mandays over control. The additional labour employment opportunities of the farming systems could be attributed to labour intensive nature of the integrated enterprises like poultry which alone contributed 24.2 per cent of the mandays.

Table 27. Employment generation in rice based integrated farming systems

Farming system	Men	Women	Total
Rice cropping alone	24	90	110
Rice - Groundnut + Mushroom + Poultry	58	292	350
Rice - Cowpea + Mushroom + Poultry	55	290	345
Rice - Brinjal + Mushroom + Poultry	78	314	392
Rice - Sunnhemp + Mushroom + Poultry	52	257	309

5. Energy budgeting

Total input energy

The mean total energy input varied considerably among the farming systems. Integration of poultry and mushroom enterprises with rice-brinjal system required the highest energy input (52,030 MJ ha^{-1}) and was followed by rice- groundnut system integrated with the enterprises (46,077 MJ ha^{-1}). However, rice cropping alone without any rice based crops or enterprises recorded the least requirement of energy. Irrigation and fertilizers for the brinjal and feed for poultry were the main components for increased energy input although use of rice bran and broken rice as supplements for poultry feed partially reduced the energy requirements of the system.

Total output energy

The mean energy output varied considerably with different systems. Integration of mushroom and poultry production with rice-brinjal system recorded the highest energy input (1,65,334 MJ ha^{-1}).

The higher energy output in this system was mainly due to the higher productivity of the cropping system which is well suited to the agro-climatic conditions. Rice- cowpea system integrated with mushroom and poultry was next best in order (1,05,627 MJ ha^{-1}). However, monocropping of rice with no enterprise linkage recorded the lowest pooled mean energy output (78,182 MJ ha^{-1}) as the system productivity was poor.

Energy efficiency

The energy efficiency which is the ratio of energy output to input varied widely among the farming systems. Cropping rice alone was found to be more energy efficient (6.76) as the integrated enterprises were not energy efficient and this was followed by integrated system of rice-brinjal + mushroom + poultry (3.18). However, rice-groundnut system integrated with mushroom and poultry recorded the lowest energy efficiency (2.24). The lower energy

Table 28. Energy budgeting for rice based integrated farming systems

Farming system	Pooled mean energy		
	Total input (MJ/ha)	Total output (MJ/ha)	Efficiency
Rice - Fallow	11563	78182	6.76
Rice - Groundnut + Mushroom + Poultry	46077	102857	2.24
Rice - Cowpea + Mushroom + Poultry	43792	105627	2.41
Rice - Brinjal + Mushroom + Poultry	52030	165334	3.18
Rice - Sunnhemp Mushroom + Poultry	41439	100911	2.44

efficiency in the integrated systems was mainly due to the higher calorific value of the commercial inputs utilised in the production system.

6. Sustainability of the system

Sustainability of the system was assessed based on the effects of cropping systems and the recycled manures from the integrated enterprises on soil and its impact on the subsequent rice crop over the period. Further, the sustainability was quantitatively assessed based on the SYI.

Impact on rice yield

Systems had a profound influence in improving grain yield of rice in subsequent seasons. The mean rice grain yield was enhanced by 18 per cent of base year (769 kg/ha increase) with rice-groundnut system as compared to rice - fallow system which recorded the least (4733 kg/ha) at the end of third season. This increase may be attributed to the crop rotation effect of the legume and also due to turning in of about 2.4 tonnes of haulms having narrow C: N ratio after harvest.

The highest rice yield (5866 kg/ha) was observed when sunnhemp was rotated with rice involving recycled FYM and was followed by rice - brinjal rotation involving paddy straw and mushroom spent substrate (5761 kg/ha) from the integrated mushroom production. The addition of sunnhemp biomass to the soil (14.89 t/ha) as green manure might have favourably influenced the soil environment through increased activity of soil microorganisms through addition of organic matter.

Similarly, brinjal rotation added 6.25 t/ha of potential usable residue to the soil that resulted in an increased organic matter content of soil, in turn favourably influencing the subsequent rice yield. Soil carbon gains are directly correlated to the amount of crop residue carbon returned to the soil. Improved soil aggregation was also associated with increase in carbon content of the aggregates. Cropping intensification also provides positive feedback to soil productivity via the increased amount of crop residue being turned to the soil.

Among the manurial resources from the integrated enterprises, recycling of paddy straw with mushroom spent substrate recorded consistently better performance with a mean yield increase of 365 kg/ha over no recycling of manure. It was followed by recycling of FYM. Addition of organic matter coupled with nutritionally rich mushroom spent substrate provided favourable environment for growth and yield of rice as was reflected through decreased chaffyness (8.4% in soils incorporated with paddy straw alongwith mushroom spent substrate in 2:1 ratio over 9.2 % in control) while the effect of FYM was visible in terms of productive tillers (11.8/hill), panicle length (19.4 cm) and filled grains (68.2/panicle) in the third season crop.

Table 29. Grain yield (kg/ha) of rice as affected by cropping systems and recycled manurial resources from the integrated enterprises

Cropping system / manurial resource	Grain yield (kg/ha)				
	M_0	M_1	M_2	M_3	Mean
Rice - Fallow					
First Year	4230	4039	4134	4917	4330
Second Year	4687	4443	4467	5333	4733
Mean	4459	4241	4301	5125	4532
Rice - Groundnut					
First Year	3855	4789	5143	5065	4713
Second Year	4872	5461	5774	5527	5409
Mean	4364	5125	5459	5296	5061
Rice - Cowpea					
First Year	4635	3747	4876	3866	4281
Second Year	5167	5688	5055	4573	5121
Mean	4901	\4718	4966	4220	4701
Rice - Brinjal					
First Year	4904	4093	4172	5150	4655
Second Year	5350	5250	4830	5761	5298
Mean	5127	4672	4501	5456	4977
Rice - Sunnhemp					
First Year	3523	5153	3505	3956	4034
Second Year	4868	5866	4766	5610	5278
Mean	4196	5510	4136	4783	4656
Mean					
First Year	**4229**	**4364**	**4426**	**4590**	**4402**
Second Year	**4989**	**5342**	**4978**	**5361**	**5168**
Mean	**4609**	**4853**	**4702**	**4976**	

- Base year (1999-2000) yield of rice is 4292 kg/ha

M_0 - No recycled manure + Recommended NPK
M_1 - Recycled FYM + Recommended NPK
M_2 - Recycled poultry manure + Recommended NPK
M_3 - Recycled mushroom spent substrate + Recycled paddy straw + Recommended NPK

Sustainability of rice yield

Among the rice based systems studied, rice-groundnut system was found to be more stable in terms of its yield potential as reflected by higher Sustainability Yield Index (0.78) and was followed by rice-brinjal system. Leguminous nature of groundnut crop with substantial leaf shedding, biological nitrogen fixation through root nodules and turning of its biomass might have contributed for its stable performance in rice-groundnut system while in rice-brinjal system, the locally adopted high yielding brinjal contributed for its stability.

Among the recycled manures, paddy straw with mushroom spent substrate recorded the highest SYI (0.75) as compared to others indicating that the practice is more sustainable in its yield influence. Further, easy availability of recyclable waste/decomposed paddy straw within the system also facilitates for its sustainable usage.

7. Effect on physico-chemical properties

In situ incorporation of crop residues (rice straw, groundnut and cowpea haulms, brinjal and sunnhemp stalks or addition of poultry manure or farm yard manure), was advantageous as reflected in improvement in physico-chemical properties of soil over the period.

Soil pH, in general was neither influenced by manures nor by cropping systems. Out of the recycled manures from the integrated enterprises, recycling of paddy straw along with mushroom spent substrate has marginally lowered the soil reaction (from 5.99 to 5.60) after two years. Among the systems, growing cowpea or groundnut was found to reduce the soil reaction marginally (5.44 and 5.47 pH, respectively from 5.99 pH) compared to brinjal (5.82 pH), sunnhemp (5.63 pH) or keeping the land fallow (5.64 pH).

Incorporation of paddy straw *in situ* along with mushroom spent substrate over

Table 30. Sustainability of rice grain yield as affected by different cropping systems over three years

Cropping system	Sustainability Yield Index				
	M_0	M_1	M_2	M_3	Mean
Rice - Fallow	0.71	0.67	0.69	0.82	**0.72**
Rice - Groundnut	0.62	0.79	0.85	0.84	**0.78**
Rice - Cowpea	0.77	0.57	0.82	0.63	**0.70**
Rice - Brinjal	0.82	0.65	0.68	0.85	**0.75**
Rice - Sunnhemp	0.55	0.85	0.55	0.61	**0.64**
Mean	**0.69**	**0.71**	**0.72**	**0.75**	

M_0 - No recycled manure + Recommended NPK

M_1 - Recycled FYM + Recommended NPK

M_2 - Recycled poultry manure + Recommended NPK

M_3 - Recycled mushroom spent substrate + Recycled paddy straw + Recommended NPK

two years had beneficial cumulative effect on soil fertility as observed in post-harvest samples after second year. The pooled data showed that on an average, these plots had 0.05 per cent more organic carbon over no recycled manure treatment. During initial period of paddy straw decomposition, although there is a temporary locking of nutrients due to immobilisation, the microbial degradation with time releases the nutrients.

Although the effect of cropping systems on soil organic carbon was not appreciable, rice-groundnut system was observed to increase the soil organic carbon marginally (1.40%). Fallowing of rice fields also served as a rotation in maintaining soil carbon status(1.36%).

Table 31. Soil reaction at the end of third year as influenced by different recycled manures from the integrated enterprises and cropping systems

Cropping system	Soil reaction (pH)*				
	M_0	M_1	M_2	M_3	Mean
Rice - Fallow	5.58	5.74	5.73	5.51	**5.64**
Rice - Groundnut	5.42	5.41	5.48	5.44	**5.44**
Rice - Cowpea	5.51	5.53	5.38	5.46	**5.47**
Rice - Brinjal	5.66	5.93	5.88	5.82	**5.82**
Rice - Sunnhemp	5.68	5.53	5.64	5.66	**5.63**
Mean	**5.77**	**5.63**	**5.62**	**5.60**	

** Soil had a initial pH of 5.99*

Table 32. Organic carbon status of soil during third year as influenced by different recycled manures and cropping systems

Cropping system	Organic Carbon (%)				
	M_0	M_1	M_2	M_3	Mean
Rice - Fallow	1.32	1.37	1.44	1.32	**1.36**
Rice - Groundnut	1.32	1.49	1.38	1.41	**1.40**
Rice - Cowpea	1.24	1.33	1.32	1.38	**1.32**
Rice - Brinjal	1.26	1.32	1.32	1.29	**1.30**
Rice - Sunnhemp	1.19	1.26	1.29	1.27	**1.25**
Mean	**1.27**	**1.35**	**1.35**	**1.33**	

** Soil had a initial organic carbon content of 0.90 %.*

M_0 - No recycled manure + Recommended NPK
M_1 - Recycled FYM + Recommended NPK
M_2 - Recycled poultry manure + Recommended NPK
M_3 - Recycled mushroom spent substrate + Recycled paddy straw + Recommended NPK

Among the recycled manures, FYM and poultry manure influenced the soil marginally to improve its fertility after successive rotation of different cropping systems (1.35%) as compared to no manure recycling. Recycling of paddy straw with mushroom spent substrate had an impact in retaining carbon status of soil(1.33%).

Thus, it may be concluded that rice-groundnut sequential cropping system may be followed for stabilized production keeping the resource base soil with better productivity. Rice-brinjal system may be followed for higher profitability in the region with use of bio-control agents.

VI. Practical Suggestions

Based on the studies conducted over a period of time at ICAR Research Complex for Goa, the following practical approaches have been suggested:

1. As mono cropping of rice is not much economical, it is wise and beneficial to follow a system approach in rice production system.
2. For low input management situations, rice-cowpea cropping systems with the use of selections in local cowpea is beneficial.
3. Rice-groundnut system is beneficial to improve soil fertility and to add to the returns.
4. Under high input management situations rice-vegetable is more beneficial. Crops like brinjal (local cultivar) with preventive measures for wilt control can fetch better returns from the system.
5. Integrated farming system approach, not only helps in recycling of wastes / by-products but also helps in productivity improvement, profitability and sustainability.
6. Rice-brinjal system integrated with backyard mushroom and poultry production with market tie-up can add substantial returns to the rice grower.

VII. Conclusions

A system approach in rice production system will aid in efficient utilization of natural resources and enhances the returns per unit of land, Adoption of selected cropping systems like rice-groundnut, rice-cowpea and rice-vegetables like brinjal depending on the situations and market potential will not only enhances the cropping intensity but also improves soil fertility.

A scientific approach in selection of varieties and crop management practices will usher in greater dividends and more importantly sustains the soil for future generations.

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