

Castor + Clusterbean with low external input IPM



Research Bulletin

Crop-crop diversity as a key component of IPM in castor



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Executive Summary

Increasing the production of oilseeds continues to be a major challenge to Indian planners and researchers for a long time. Among oilseeds, castor is the most important non-edible oil seed crop. The crop is largely grown in rainfed conditions as a *kharif* crop. Of the various factors that constrain productivity, incidence of insect pests is an important factor. Farmers in the rainfed regions, with their limited investment capacity cannot afford input-intensive plant protection measures. Castor is often grown as sole or along with other crops in intercrop situations that are popular in the rainfed regions. Adoption of intercrops offers scope to manipulate the growing environment such that the crop is better protected by the natural ways of pest management. There is also a strong need to develop pest management practices that are affordable for the resource-poor farmers.

Inter- and mixed cropping systems, the popular forms of crop-crop diversity, have become more popular in the rainfed regions. These systems provide opportunities to create situations that are less pest-prone compared to the sole crop situations or the monocultures. Efforts were therefore made to identify intercropping systems that attract less pest incidence and when combined with other components of integrated pest management, minimize least investments on plant protection without significant losses in yields and income. Specifically, an attempt was made to identify the intercrops in the presence of which castor suffers less pest incidence, and a low external input IPM module for economic pest management.

The diversity created by introducing clusterbean, cowpea and greengram as intercrops in castor resulted in a build up of natural enemies of the major pests of castor and also resulted in less congenial conditions for insect pests. As a result of the changes in microclimate and build up of natural enemies, there was much less pest incidence and damage in castor intercropped with clusterbean, cowpea and greengram compared to sole castor. Further these systems were more efficient agronomically in terms of land equivalent ratio, aggressivity, competitive ratio and relative crowding coefficient. Economic analysis also showed these intercropping systems to be more profitable than sole castor. The adoption of low external input integrated pest management (LEIIPM) module consisting of sequential application of 5% neem seed kernel extract, 5% neem oil, 1/10 w/w extract of *V. negundo*, 5% pongamia oil, erection of bird perches and mechanical collection of larvae was effective in managing/controlling the pests. Choice of castor intercropping with either clusterbean or cowpea or greengram may be integrated into the effective LEIIPM module as a component.

Crop-crop diversity as a key component of IPM in castor

1. Introduction

The green revolution of the late 1960s, responsible for rapid agricultural growth, was largely confined to irrigated areas bypassing the vast rainfed tracts. Nearly half of the cultivated area in India will remain rainfed even after realizing the full irrigation potential. Rainfed areas produce bulk of coarse cereals, pulses, oilseeds and fiber crops. More importantly, rainfed regions provide livelihood to a majority of rural poor and as a result they are often described as hot spots for civic strife. The productivity of crops grown in rainfed areas is considerably lower than the potential and much lower than that of irrigated crops. Enhancing this productivity is therefore important for growth, equity and sustainability in the farm sector.

Crop production in rainfed regions is by nature dependent on monsoon behaviour and is therefore highly risky. Rainfed regions are also highly heterogeneous in terms of land terrain, soil productivity, climate and socio-economic conditions, all of which influence the crop productivity. Another important factor that affects crop production is the incidence of pests and diseases. With the poor capacity of the farmers to invest on plant protection measures, the incidence of pests and diseases often leads to significant losses of productivity and income to the farmers.

As an insurance against biotic and abiotic stresses, farmers in rainfed regions have diversified their farming systems. Rainfed regions are thus more diversified in cropping systems compared to irrigated areas. Small and marginal farmers in rainfed areas generally grow more crops per unit area as inter and mixed cropping systems (Walker and Ryan, 1990). These systems, meet the diverse family needs and also are less prone to pests and diseases. As the components in the system differ in their growth behaviour and nutrient and water requirements, it helps in risk minimization.

Dependence on chemical pesticides has led to the problems such as insect pest resistance, resurgence and escalating cost of cultivation. Considering the ill effects of chemical pesticides and the growing preference for chemical-free food products, efforts are under way to develop and popularize Integrated Pest management (IPM) technologies. Such technologies need to be affordable by the farmers and should fit into the existing farming systems. Research revealed that farmers adopt such components of IPM as intercropping and border crops more readily. In other words, cultural components of IPM need to be emphasized more as they require relatively less external inputs and are more likely to be adopted by the farmers.

Crop diversity is a situation wherein different crops are grown simultaneously. Crop-crop, crop-border and crop-weed diversities are different forms of crop diversity (Baliddawa, 1985). Intercropping and mixed cropping systems are more popular forms of crop-crop diversity practiced in rainfed agriculture. These systems provide situations that are less pest-prone compared to the monocultures. The genetic uniformity of monocultures leads to susceptibility to pests (Bhatnagar and Davies, 1979). The factors that contribute to reduced pest populations

in intercropping include physical protection from wind, shading (Litsinger and Moody, 1976), prevention of dispersal (Kayumbo, 1975) production of adverse stimuli, olfactory stimuli camouflaged by main crop (Aiyer, 1949), presence of natural enemies (Russell, 1989 and Tonhasca, 1993) and availability of food (Fukai and Trenbath, 1993) Research in diversified agro-ecosystems demonstrated that these systems tend to support less herbivore load than the corresponding monocultures (Altieri and Letourneau, 1982 and Risch, 1981). Thus, there is considerable scope to develop a system that is diverse and less prone to pests and diseases. When other pest management technologies are superimposed on such systems, it becomes much easier and cheaper for the farmer to manage the pests rather than in monocultures which are more prone to pest incidence and require considerable investments in pest management. Low external input IPM (LEIIPM) seeks to optimize the use of local available resources by combining different components of farming system.

Keeping these considerations in view, research was conducted to harness the potential benefits of crop-crop diversity by identifying intercropping systems that are less prone to pest incidence, more efficient, remunerative and acceptable to farmers. We focused our efforts on castor, a major rainfed oilseed crop that suffers from serious damage by insect pests necessitating higher investment by the farmers. This publication summarizes such work carried out by CRIDA during 2003-2005. A considerable part of the research was funded by the ICAR in the form of an AP Cess Fund project “*Crop-crop diversity as a key component of IPM in dryland crops*”.

Castor (*Ricinus communis* Linn.) is an important non-edible oilseed crop grown across many parts of the arid and semi-arid regions in the country. This crop is an important cash crop grown by the farmers. Castor is grown for its beans from which oil is extracted. Castor oil is mainly used in manufacture of paints, lubricants, soaps, hydraulic brake fluids, polymers, perfumery products, etc. There are several derivatives of castor oil, which are used in a variety of industries.

The fluctuations in productivity levels of castor arise from two main reasons. First, it is grown as a *kharif* rainfed crop and being a long duration crop is subject to the vagaries of the monsoon. Second, it attracts a number of pests, the semilooper and shoot and capsule borer being the major ones. (In certain pockets, wilt and grey mould diseases also reduce the productivity.)

Semilooper, *Achaea janata* and shoot and capsule borer, *Conignethes punctiferalis* occur during early and late stages of crop growth, respectively (Singh, 1987). Incidence of semilooper is generally noticed from vegetative to early reproductive phase of the crop (Tahiliani, 1985). Semilooper causes excessive defoliation affecting photosynthesis at the peak level of infestation. Later, the larvae eat away the tender capsules of primaries and secondaries. It is estimated that yields are reduced by 30-50% due to semilooper alone. Incidence of shoot and capsule borer is commonly noticed in the later stage of crop growth, especially secondaries and tertiaries. Larvae web the tender capsules, bore into them and eat away the kernel. The borer attacks various plant parts –shoots, inflorescences and capsules, causing considerable yield losses (Singhvi *et al*, 1972). In castor, excessive branching allows the plant to have a unique plant structure and offer scope for manipulating the environment with different intercrops for possible reduction in incidence of insect pests. Keeping these considerations in view, we attempted to examine how the incidence of insect pests differs in a crop-crop diversity system compared to a sole crop situation.

2. Methodology

A two-step methodology was followed to achieve the intended objectives. In the first step, experiments were conducted on farmers' fields to test the impact of intercrops on various insect pests of castor crop. Combinations found effective along with some other systems popular with the farmers or suggested by them were evaluated in farmers' fields. In the second step, different LEIIPM modules were superimposed on the systems found effective and efficient in the earlier steps.

2.1 Identification of effective intercrop

Field experiments were conducted during rainy seasons of 2003, 2004 and 2005 in a randomised block design (RBD) to create crop-crop diversity systems. Eight intercrops were tested with castor as the base crop in farmers' fields and also in the research farm of CRIDA. Ten farmers who served as replications grew each system. The villages and farmers selected represent typical dryland farming situation. Various participatory rural appraisal (PRA) tools were used to identify the farmers and ensure their participation. The experiments were subjected to analysis of variance (ANOVA) for RBD.

2.2. Low external input IPM modules

Three low external input IPM modules were evaluated in three most effective crop diversified systems identified in the earlier step. These experiments were also taken up on-station and in farmers' fields with the active participation of the farmers during 2005.

The sequential application of various components was adopted in different ways. The low external input IPM modules were —

IPM I: Neem Seed Kernel Extract (NSKE) 5%, extract of *Vitex negundo* 1/10 w/w, NSKE 5% and extract of *V. negundo* 1/10 w/w

IPM II: Neem oil 5%, Pongamia oil 5%, Jatropha oil 5%, Neem oil 5%

IPM III: NSKE 5%, Neem oil 5%, extract of *V. negundo* 1/10 w/w, Pongamia oil 5%

All modules included bird perches and mechanical collection of larvae by shaking of the plants.

The pest population and yield data were subjected to ANOVA for two factor RBD with the IPM module as factor 1, intercrop as factor 2 and the individual farmer as replicate.

2.3. Data Set

Weekly insect counts were recorded from ten randomly labeled castor plants in each plot at various stages of crop growth in the on-farm and on-station experiments. Three terminals per plant were selected. Field observations of insect pest and predator (coccinellids and spiders) populations were recorded during the cool hours of the day (7 to 9.30 am and 4 to 6 pm) as per



standard procedure (Pradhan, 1964). The percent parasitism by *Microplitis maculipennis* was estimated by collecting 20-25 neonate larvae of semilooper from each intercropping system at fortnight intervals and mean of six observations was presented and later average of two years was given in this bulletin.

Data on microclimate variables were also recorded at weekly intervals to measure differences in microclimate among intercrop canopies. Canopy temperature (Tc) and canopy air temperature differential (CATD) were recorded from three locations in each plot, using Teletemp AG-42 Infrared Thermometer *. Relative humidity within crop canopy was determined by using Digital Psychrometer at regular intervals (Kumar *et al*, 1999).(*Not the recommendation of Institute)

The data on the weekly observations on pest incidence, natural enemies, weather parameters etc was subjected to ANOVA as applicable (Gomez and Gomez, 1984). The yield data were further used to construct various indices such as Competitive Ratio (CR), Aggressivity (A), Relative Crowd Coefficient (RCC), Land Equivalent Ratio (LER) against which the treatments were evaluated using standard procedure (Rao and Willey, 1980). Economic analysis was done by considering the market prices of the inputs used and farm harvest prices (FHP) of the crops concerned.

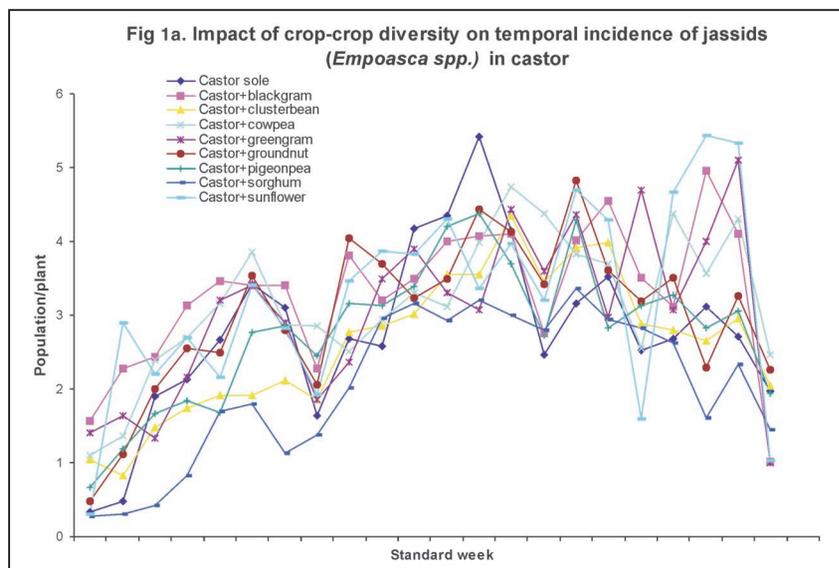
3. Results

3.1. Impact of crop-crop diversity on insect pests

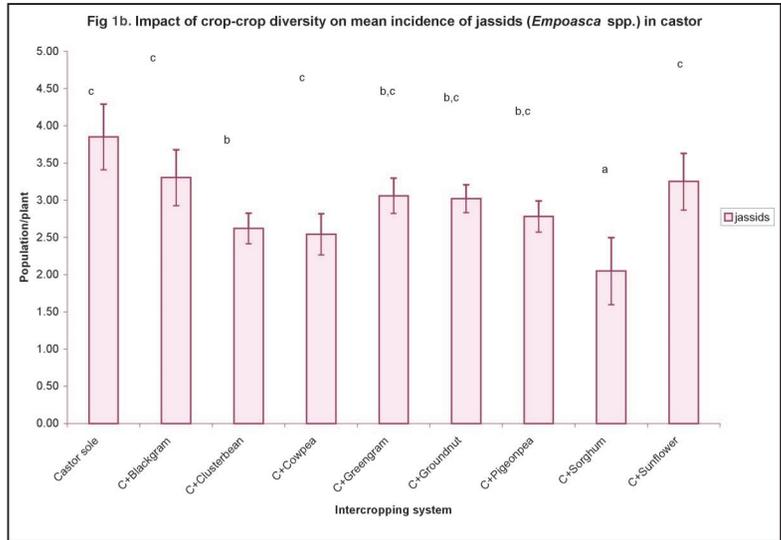
In castor based intercropping systems, the incidence of leafhopper, *Empoasca flavescens*, semilooper, *Achaea janata*, whitefly, *Trialeurodes ricini*, tobacco caterpillar *Spodoptera litura* and shoot and capsule borer *Conignethes punctiferalis* were predominantly noticed. The impact of castor based intercropping systems on the incidence of these insects is discussed hereunder.

Empoasca spp.

The population of adult leafhopper fluctuated across different intercropping systems during the crop period and temporal variation was much evident. The infestation of leafhopper was observed from 31st - 52nd SWK (Fig. 1a). It can be noted that the



leafhopper population was low in majority of intercropping systems up to 42nd SWK and thereafter increased till 51 SWK. A high population of leafhoppers/plant was observed during 49 - 51 SWK in castor + greengram, castor + sunflower and sole castor (in the range of 2.68-5.43 per plant). The intercropping systems viz., castor + clusterbean, castor



+ sorghum and castor + cowpea recorded low level of incidence over time. The mean population was also significantly lower in these systems (2.05-2.62per plant) (Fig 1b), while moderate level of pest incidence was noticed in castor + blackgram and castor + groundnut systems.

A.janata

The incidence was noticed during 31 – 38 SWK in majority of intercropping systems and later it was found to be very sparse and low (Fig. 2a) (plate 1). The incidence of semilooper was unimodal with peak infestation noticed during the 32-37 SWK (range of 3.5-4per plant), coinciding with the formation of primaries and the incidence varied across the intercropping systems. A perusal of data illustrated that the intercropping systems viz., castor+ clusterbean, castor + cowpea and castor + pigeonpea recorded low level of pest incidence. The higher level of semi looper population was observed in castor+ greengram, castor+ blackgram, castor+ groundnut and sole castor. Similar trend was observed with means incidence of *A.janata* across intercropping systems and was significantly less (0.78-0.88 per plant) in castor+clusterbean castor+cowpea and castor+pigeonpea (Fig 2b).

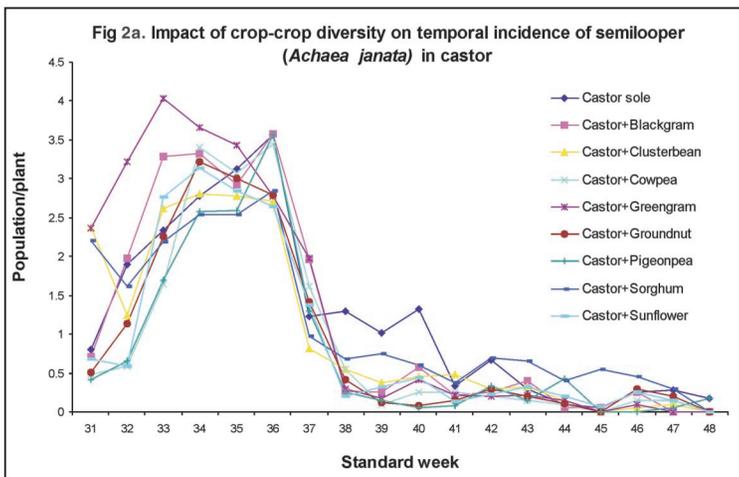
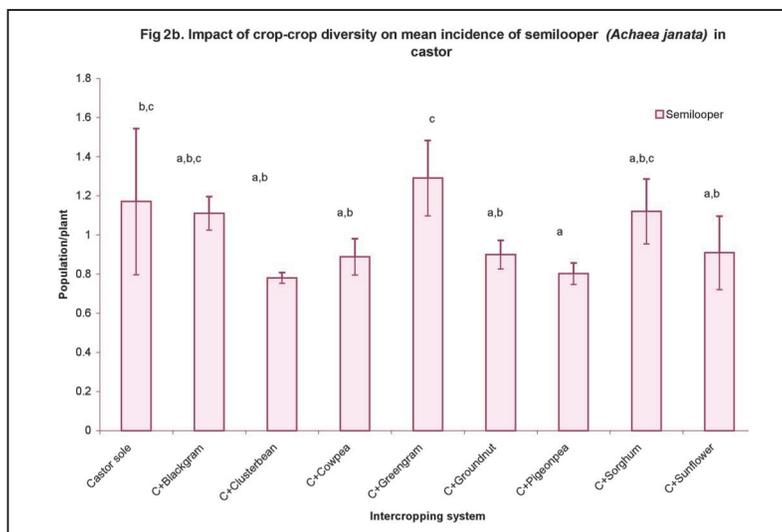


Plate 1 : Semilooper on Castor



T.ricini

The initial incidence of whitefly (plate 2) occurred during 30th SWK and continued till 52nd SWK. The whitefly population fluctuated widely among all the intercropping systems from early stage to harvest of the crop. Castor + cowpea, castor + soybean, castor + sunflower and castor + pigeonpea recorded higher population than sole castor. The intercropping systems such as castor + sorghum, castor + blackgram and castor + groundnut recorded low level of whitefly incidence.



Plate 2 : *T.ricini* on Castor leaf

S.litura

The incidence of *S.litura* occurred during 35th SWK and continued till 48th SWK and later the incidence was reduced. The pest population fluctuated widely among all the intercropping systems from early stage to harvest of the crop. The incidence of *S.litura* was unimodal and peak incidence occurred during 39-46 SWK in castor with intercrops like sorghum, greengram, and sole castor recorded higher larval population followed by castor+ sunflower. Low level of population was noticed in castor+ cowpea, castor+ groundnut than sole crop of castor.

C. punctiferalis

The effect of different intercropping systems on the population of capsule borer was significant. The data recorded on damage caused by capsule borer across intercropping systems was collected individually spike order wise (primaries, secondaries and tertiaries). The damage was less in castor crops with sorghum, clusterbean and pigeonpea compare to other systems. Blackgram, cowpea and groundnut as intercrops recorded significant low level of capsule damage and were the next best.

3.2. Impact of crop-crop diversity on natural enemies

The occurrence of endo-parasitoid *Microplitis* on semilooper was monitored at weekly intervals and neonate larvae were collected and reared in laboratory and formation of cocoon at posterior region of larvae were recorded and adult emergence of braconid was represented as percent parasitism.

The occurrence of the common predators of insect pests of castor was monitored at regular intervals in different intercropping systems. Among various species of coccinellid predators, viz., *Menochilus sexmaculatus* (F), *Brumoides suturalis* (F), *Illois indica* Timberlake, *Coccinella transversalis* (L) and *Coccinella septempunctata* (L), *M. sexmaculatus* was found most dominant accounting for more than 80% of the total coccinellid population. The coccinellids were considered as a group and their presence was recorded in all the intercropping systems.

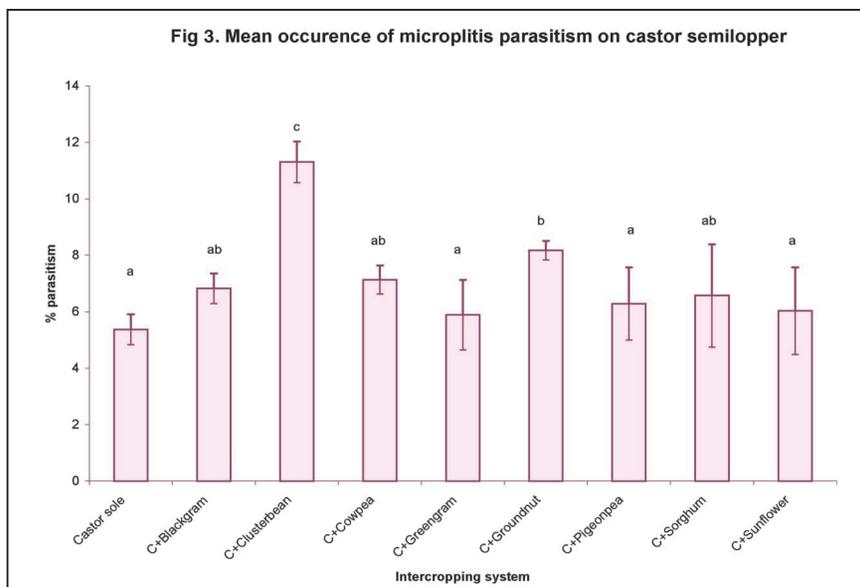
Four species of spiders were observed in the intercropping systems under study. These belong to the families Clubionidae, Araneidae, Linyphilidae, and Thomisidae. Among various spiders recorded, *Clubiona* spp was dominant. All the spiders irrespective of the family to which they belong were recorded together as one unit.

Microplitis

The presence of *Microplitis* cocoon (Plate 3) at posterior end of larvae and adult emergence was recorded and noted as an indicator of parasitism. The percent parasitism varied across intercropping systems and in the range of 5-11 percent. Higher level of parasitoid attack on semilooper was recorded in castor+clusterbean (11%) followed by castor+groundnut, which were significantly higher than the rest of the systems. The activity of parasitoid was more on castor with cowpea, blackgram and sorghum as intercrops (Fig 3).



Plate 3 : *Microplitis* cocoon on Castor semilooper



Coccinellids

The activity of coccinellids (plate 4) was recorded within a month after sowing (31 SWK) and continued up to 44 SWK and later sparse level of population was noticed. The peak activity of coccinellids (0.5-0.8 per plant) was recorded during the formation of primaries in all intercropping systems during 33-38 SWK periods (Fig 4). The coccinellid population varied significantly across intercropping systems throughout the crop growth period. Systems like castor+ clusterbean, castor+ cowpea, castor+ blackgram and castor+ greengram nurtured significantly higher population of coccinellids than the rest of intercropping systems and was reflected in the mean occurrence also (0.39-0.48 per plant) The intercropping systems viz., castor+ sorghum, castor+sunflower and sole castor recorded low level of 2-4 coccinellids per ten plants.

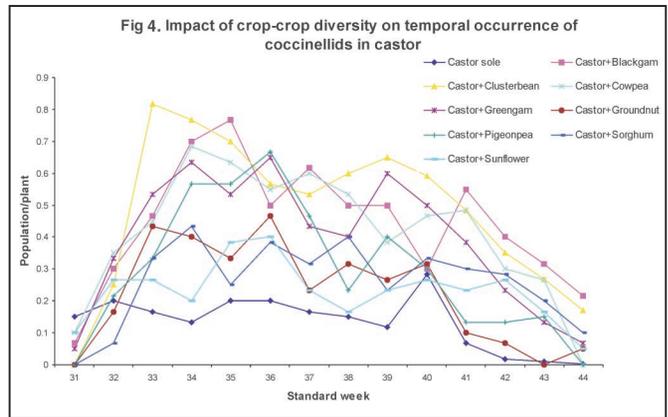


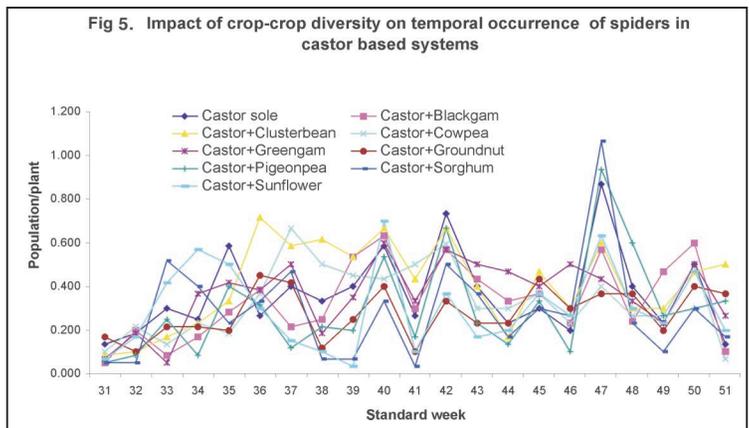
Plate 4 : Coccinellids (*monochilus*, *coccinella* sp)

Spiders

The activity was noticed from 31 – 51 SWK period and variation of population was evident across intercropping systems (plate 5). The data were analysed and mean population was depicted in figure 5 data. The fluctuation of population was significant among intercropping systems and the spider activity was significantly higher in castor+ clusterbean (0.78-0.88 per plant) over time. Similar trend was observed with mean occurrence of spiders during crop growth period.



Plate 5 : Spiders (*clubiona* sp)



Other parasitoids

The occurrence of other parasitoids viz., egg parasitoid *Telenomus* and *Trichogramma* sp are noticed on eggs of semilooper. The level of parasitism was sparse (< 5%). The other larval parasitoid *Euplectrus* sp is gregarious ecto parasitoid attacking semilooper larvae from outside and nearly 5-10 feed on a single larva (plate 6).



Plate 6 : *Euplectrus* sp on semilooper and death of larva

3.3. Microclimate (Abiotic) factors

Variation in microclimate variables (plate 7) across castor based intercropping systems was noticed. The variables like canopy air temperature varied during the crop period (Fig 6). Higher T_c values were recorded during the early stages of crop (34-38th SWK) and were in the range of 30-40°C with a variation of 3-5°C across intercropping systems. During early stages of crop, castor + greengram, castor + blackgram and castor + cowpea recorded higher temperatures. Long stature intercropping systems like castor+maize, castor + sunflower and castor+sorghum recorded lower temperatures during middle of the crop period.

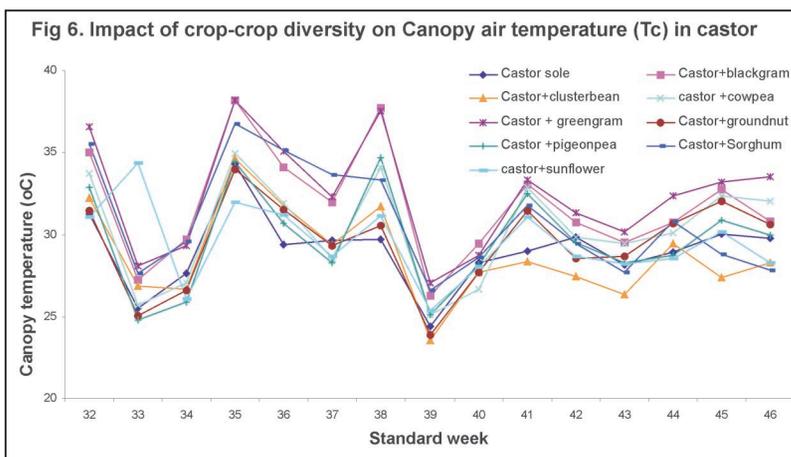


Plate 7 : Recording of CRH and canopy air temperature

3.4. Agronomic efficiency

Fresh and dry weights of castor

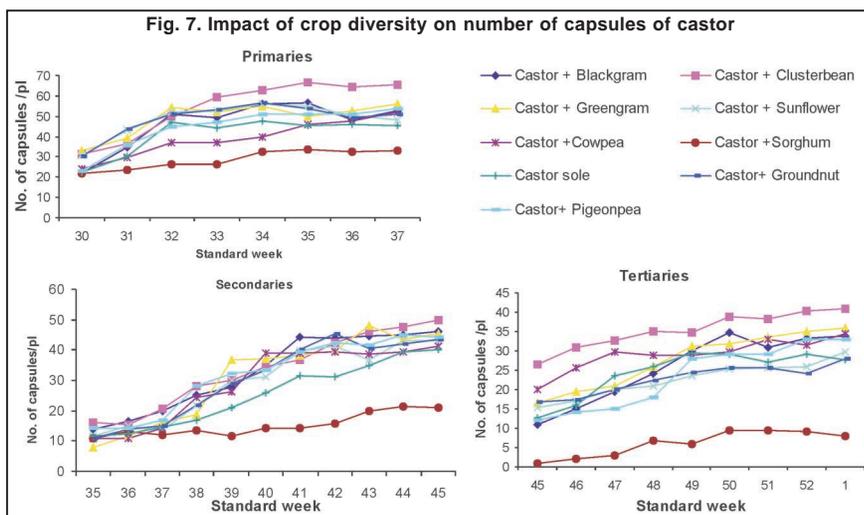
The fresh weights of castor were recorded across the intercropping systems at regular intervals. Distinct variation in dry matter accumulation was observed from 75DAS and trend was maintained till the harvest of the crops. Castor + clusterbean recorded the highest fresh weight till the end of the intercropping system. This was followed by castor + blackgram, castor + greengram and castor+ groundnut. Lowest fresh weight was recorded in castor + sorghum

because of tall and lanky growth of plants which might be due to competition between main and inter crops. Similar trend was observed with the dry weights also. Highest dry weights were recorded in castor + clusterbean, castor sole, castor + blackgram, castor + greengram and castor + cowpea in descending order. The lowest dry weights were recorded in castor + sorghum followed by castor + sunflower and castor + pigeonpea.

Number of capsules in castor

The number of capsules borne on three different spike orders varied markedly across intercropping systems. A prominent difference was observed in number of capsules on primaries from secondaries and tertiaries. Primary capsules were in the range of 15-60 in number where as secondaries and tertiaries were in 10-40. In all other intercropping systems except castor+sorghum system, number of capsules was more than sole castor.

A perusal of the results indicated that number of capsules in primaries was more in castor+ clusterbean system followed by castor+ groundnut (35-60per plant). Moderate level (30-45per plant) of capsules on primaries were



recorded in castor+ blackgram, castor+ cowpea and castor+ greengram systems. While the intercropping systems viz., castor with sorghum and maize recorded minimum number (15-30per plant) of capsules on primaries, the systems like castor+ clusterbean, castor+ blackgram, castor+ greengram, castor+ groundnut and castor+ cowpea systems recorded highest number of capsules from secondaries and tertiaries, (Fig 7). The least number of capsules from secondaries and tertiaries were recorded in castor + sorghum and castor+ sunflower systems.

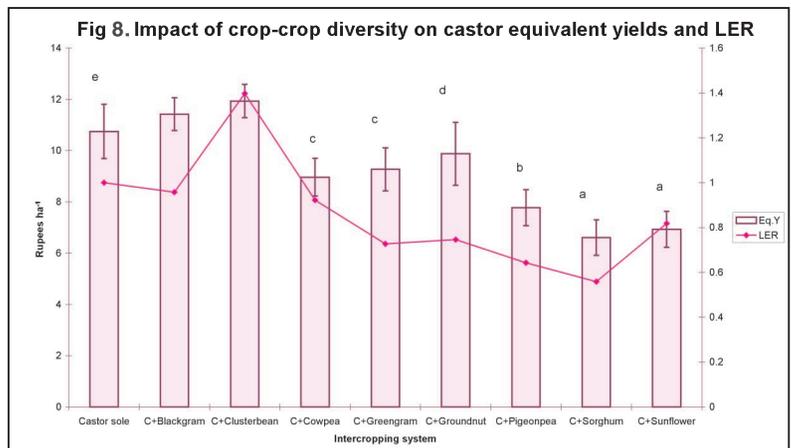
Castor equivalent yields and LER

The castor equivalent yields were significantly higher in castor with clusterbean (11.93qha⁻¹) (plate 8) followed by blackgram (11.42 qha⁻¹) as intercrops (Fig 8). Lower equivalent yields were recorded in castor + sorghum (6.60 qha⁻¹), castor + sunflower (6.93 qha⁻¹) and castor + pigeonpea (7.70 qha⁻¹) than sole castor. The intercropping systems were evaluated with respect to land utilization point of view and land equivalent ratios were presented in fig 8. The LER values were highest in



Plate 8 : Proud farmer with good harvest

castor + cluster bean (1.45) followed by castor+ blackgram and castor + cowpea i.e. more than one. All remaining systems recorded low LER values than sole castor. Lowest LER was observed in castor with sorghum (0.56) followed by pigeonpea (0.64) and greengram (0.73) as intercrops.



Agronomical indices of intercropping systems

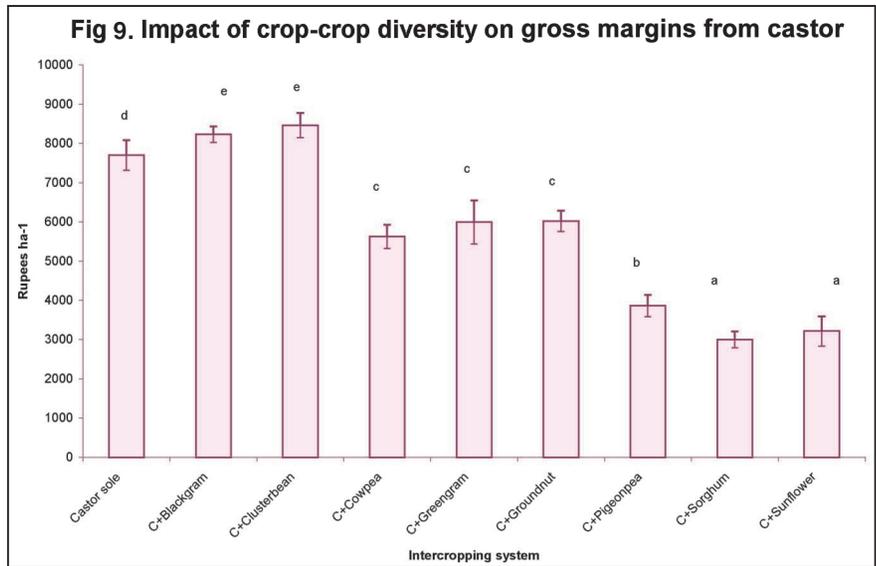
The agronomic evaluation of intercropping systems indicated that aggressivity (A) values for castor were positive and those of intercrops were negative showing the dominance of the main crop (castor) except castor+ sorghum and castor+ pigeonpea systems. Highest aggressivity was observed in castor + clusterbean (0.254) followed by castor + groundnut and castor + blackgram. In these systems mainly, castor+ sorghum system, castor crop was smothered by sorghum and the values of main crop was negative (-0.090) and intercrop was positive. In other systems the trend indicated that castor was vigorous in growth and was dominant in the mixture. The higher competitive ratio (CR) values for castor were observed with clusterbean (1.417) than blackgram (1.271) and groundnut (1.257). The competitive ratio values showed that castor was more competitive than the intercrops and the difference between CR values of main and intercrops was more in castor + clusterbean (0.715) and castor+ pigeonpea (0.818) and indicated that intercrops were not suppressed significantly by the main crop. The differences between CR values of main and intercrops were less in castor+sorghum and castor+ sunflower systems. The relative crowd coefficient (RCC) values for castor were more than unity and were high in castor+clusterbean (4.699). However, the rest of systems like castor+groundnut, castor+ blackgram, castor+cowpea and castor+ greengram recorded more than unity values. RCC was lower than one in castor+sorghum, castor+sunflower and castor+pigeonpea systems. (Table 1).

Table 1. Agronomic evaluation of castor based cropping systems

	Competitive Ratio		Aggressivity		Relative crowding coefficient	
Castor+ Blackgram	1.271	0.803	0.148	-0.148	1.659	0.984
Castor+ Clusterbean	1.417	0.702	0.254	-0.254	4.699	0.971
Castor+ Cowpea	1.092	0.914	0.061	-0.061	1.487	0.935
Castor+ Greengram	1.188	0.857	0.091	-0.091	1.147	0.721
Castor+ Groundnut	1.257	0.796	0.151	-0.151	1.895	0.895
Castor+ Pigeonpea	0.961	0.143	-0.140	0.140	0.422	0.861
Castor+ Sunflower	1.110	0.901	0.060	-0.060	0.807	0.688
Castor+ Sorghum	0.819	1.228	-0.090	0.090	0.480	0.765
SE m±	0.092	0.021	0.016	0.016	0.443	0.043
CD (0.05%)	0.278	0.063	0.048	0.048	1.344	0.13
CV%	13.71	4.45	51.62	51.62	49.47	11.04

3.5. Economics:

The economics of castor based intercropping systems revealed that highest costs on various components were incurred in castor + groundnut (Rs.5444.7 ha⁻¹) and castor + cluster bean (Rs.5370 ha⁻¹) followed by castor+ pigeonpea



(Rs.5042 ha⁻¹), castor+ blackgram (Rs.4944 ha⁻¹). The cost structure indicated that human labour and seed value were the most important factors contributing to the total cost and the relative expenditure on seed and labour was also more in case of intercropping systems compared to sole castor. The gross margin as indicated by returns over variable costs was found to be highest in case of castor+ clusterbean and castor+ blackgram. The systems like castor+ sorghum and castor+ pigeonpea recorded less returns. (Fig.9)

Table 2. Composition of variable costs in different cropping systems (Rs /ha)

	Seed value	Fertiliser	Human labour	Bullock pair	Total
Castor sole	210(43.6)	1275 (28.2)	1720(38.1)	1313(29.0)	4517(100)
C+Blackgram	473(9.4)	1275(25. 2)	2002(39.6)	1313(25.9)	5063 (100)
C+Clusterbean	734(12.8)	1525 (26.5)	2180(37.9)	1313(22.8)	5752 (100)
C+Cowpea	432(8.6)	1275 (25.5)	1986(39.7)	1313(26.2)	5005 (100)
C+Greengram	326(6.7)	1275 (26.2)	1961(40.2)	1313(26.9)	4875 (100)
C+Groundnut	808(13.9)	1587 (27.3)	2118(36.4)	1313(22.5)	5826 (100)
C+Pigeonpea	405(7.9)	1276 (24.95)	2118(41.4)	1313(25.7)	5111 (100)
C+Sunflower	365(7.0)	1588 (30.47)	1945 (37.3)	1313(25.2)	5210 (100)
C+Sorghum	304(5.7)	1713(32.1)	2013 (37.7)	1313(24.6)	5342 (100)

The variable costs of cultivation of the intercropping systems considered are presented in table 2. It can be seen that inclusion of intercrops increased the cost of cultivation in all cases. The cost of cultivation was highest in case of castor+ groundnut and castor+ clusterbean systems (Rs. 5825.92, ha⁻¹, 5751.67). A look into the cost structure indicated that human labour was the most important factor contributing to the total cost. In case of castor+ groundnut, the expenditure on seed was found to account for about 18% of total variable costs.

The effective and efficient systems were further taken forward wherein different IPM modules were superimposed and evaluated for their effectiveness and profitability.

Significant differences in pest incidence were observed among intercropping systems. Pest incidence on castor was lower when intercrops were grown between castor rows compared to sole crop of castor. The intercrops possibly acted as physical barriers to the movement of insects

across rows of castor. Deterrence of colonization through intra field diversity is probably one of the promising means of controlling insect pests because only a little additional diversity in the crop field may have a profound effect on colonization by insects and was well documented in case of intercropping (Risch *et al.*, 1983). Any such delay in pest colonization therefore results in subsequent delays in the pest buildup. Clusterbean and cowpea were particularly effective in reducing the pest incidence. The present results showed that intercropping had positive influence with castor + clusterbean dicrop combination which reduced the infestation.

Clusterbean and cowpea as intercrops facilitated the natural proliferation of predators and recorded higher populations of coccinellids and spiders. Dhuri *et al.*, (1986), Duffield and Reddy (1997) reported increased activity of coccinellids and spiders in leguminous intercrops. The low incidence of insect pests in intercrop systems has often been attributed to one factor i.e, higher abundance of their parasitoids and predators, which supports the 'natural enemies hypothesis'. Aphids in cowpea and whitefly in clusterbean represented the main prey, which in turn attracted these generalist predators. Similarly higher population of these predators were recorded in another crop like cotton (Venugopal Rao *et al.*, 1995 and Parajulee *et al.*, 1997 and Balasubramanian *et al.*, 1998).

These predators on cowpea and clusterbean might have exercised a regulatory effect on pests of castor. Baliddawa (1985) observed that up to 30% of pest reduction in intercropping systems could be due to the 'natural enemy effect'. The greater effectiveness of clusterbean and cowpea in reducing the insect pests on castor can be attributed to the combined operation of barrier and natural enemy effect.

Many herbivores especially those with narrow host range (like castor semilooper) are most likely to find and remain on host plants that are concentrated i.e. that occur in large dense or pure stands which constitute the principle of *resource concentration* hypothesis. *Associational resistance* refers to the reduced herbivore attack that a plant experiences in association with taxonomically different diverse plant is possible or noted with above intercropping systems. The associational resistance is due to either resource concentration or natural enemy hypothesis or both.

Castor+ sorghum intercropping system recorded low incidence of insect pest population. Although it is not a legume, sorghum as intercrop reduced the pest incidence in castor. Because of its faster growth and canopy formation sorghum crop suppressed the castor plants and making them small and lean. Plants suppressed in this way may become less attractive to a pest or provide a less suitable food source; alternatively, the smaller suppressed plants may constitute a less efficient crop for passively dispersing individuals of attacking organism (Trenbath, 1993).

3.6. Low external input IPM modules

Three systems namely castor+ clusterbean, castor+ cowpea and castor + greengram were found to perform better in terms of lower pest incidence, better LER and higher gross margin. On these three systems three IPM modules as defined in section 2.3 were superimposed. All these modules consisted of only farm generated inputs. The findings from a two factor RBD analysis showed that the three modules and the three intercrops differed significantly in terms of incidence of pests and equivalent yields.

The incidence of *A.janata* varied across treatments having different combinations of intercrops and IPM modules. The incidence in terms of both CPU and mean population per plant varied significantly across the treatments. The effect of both the factors was found significant. The incidence of *A.janata* was particularly low in castor when intercropped with clusterbean (22.73 CPU and 3.78 larvae/plant) and when protected with IPM module III (28.51 CPU and 4.75 larvae/plant). The interaction effect was also found significant. Similar results were obtained in case of leafhopper also. The incidence of *Empoasca* sp was low in castor + clusterbean when protected with IPM module I and III . The interaction effect was also found non significant. These differences in pest infestation were also reflected in the seed yield. The equivalent yields were more when clusterbean and cowpea were grown as intercrops in castor (14.50 and 11.09 q/ha) with IPM III (11.68 q/ha)

The IPM III module (consisting of sequential application of botanical extracts, oils, erection of bird perches and mechanical collection of larvae) on castor + clusterbean was found to suffer least pest incidence, attract more natural enemies, give higher yields and returns, followed by the castor+ cowpea system. These two systems can thus serve as a cultural component or platform on which the low external input or bio-intensive modules of crop protection can be adopted. These modules were also comparable to the recommended IPM package in terms of pest management and yields. However the cost incurred in LEIPM modules was much less because of the avoidance of external inputs like bio agents and chemical insecticides.

4. Farmers' Feedback

Focus group discussions were held with farmers before commencement of the on farm experiments. It came out during the interactions that farmers were practicing the sole crop of castor as a routine practice. Not many farmers were aware about the advantages of crop-crop diversity in terms of lowering of pest infestation. Adoption of chemical insecticides was little (not much evident). Though some farmers were aware about various components of IPM, adoption was not significant.

Similar focus group discussions were held again at the end of the project with the same set of farmers as before. Farmers expressed that the diverse crop systems in fact suffered less pest infestation than the monocultures. Farmers were asked to rate each intercropping system on a scale of 1 to 10 with respect to three parameters viz., pest incidence, yield and cost of cultivation. The obtained average indicated that the castor + clusterbean system fared better with a score of 3.62 for pest incidence, 7.02 for yield and 5.21 for cost and was considered superior to all other systems. However, the costs incurred were least with sole castor. Farmers also opined that the yield from the castor + groundnut and castor+ cowpea systems were comparable to that of castor+ clusterbean, but required high investments towards seed and picking charges. In all the systems, bullock labour was used for preparatory cultivation, sowing and interculture. Thus the cost of bullock labour was same in all the systems.

As a result of frequent visits by project staff, farmers are now able to recognize a number of insect pests, their feeding habits and natural enemies as well. The benefits of choosing an intercrop in terms of higher yields, saving on cost and better cash flow are also better appreciated

by the farmers. Farmers were also convinced about the effectiveness of LEIPM modules. However, how this awareness translates into action remains to be seen. Yet, since the components tested are easily adoptable, it is expected that farmers will adopt LEIIPM components easily compared to the other practices.

5. Conclusions

The diversity created by introducing clusterbean or cowpea or greengram as intercrops in castor resulted in a build up of natural enemies (*Microplitis*, *Euplectrus*, coccinellids and spiders) of the major pests of castor and also resulted in less congenial conditions for insect pests. As a result of the changes in microclimate and build up of natural enemies, there was much less pest incidence and damage in castor intercropped with clusterbean, cowpea and greengram compared to sole castor. Further these systems were more efficient agronomically in terms of land equivalent ratio, aggressivity, competitive ratio and relative crowding coefficient. Economic analysis also showed these intercropping systems to be more profitable than sole castor. It can be concluded that these systems are better protected from adverse climate as well as pest attacks, resulting in higher yields and economic returns. The adoption of Low External Input Integrated Pest Management module consisting of sequential application of neem seed kernel extract 5%, neem oil 5%, extract of *V. negundo* 1/10 w/w, pongamia oil 5%, erection of bird perches and mechanical collection of larvae was found effective in managing/controlling the pests. Growing clusterbean or cowpea or greengram as intercrops in castor can therefore be a component in LEIIPM module

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Some examples of crop-crop diversity in castor



Castor + sepeboon



Castor + okra



Castor + sunflower



Castor + pigeon pea



Castor + cowpea

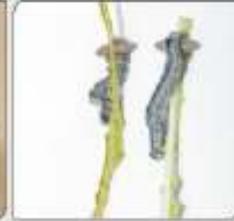


Castor + eggplant

Parasitoids



Microplitis stali and cocoon



Microplitis sp. on castor seedling pupa



Egletes sp. on castor seedling pupa

Insect pests



Castor seedling pupa



Defoliation of castor by sawfly pupa



Damaged beans



Shriveled and capped bean