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Influence of intercropping system on insect pests and viral diseases of tomato, *Lycopersicon esculentum* Mill.

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Abstract: Studies to assess the effects of intercropping in tomato under irrigated and rainfed conditions for the management of key pests at Regional Research Station, Paiyur, TamilNadu Agricultural University, TamilNadu during 1998-2000. Experiments were conducted in a factorial randomized block design using intercrops *viz*, clusterbean, green gram and mustard and two rounds of spraying with NSKE 5% and monocrotophos 0.07%, once on 30th day after transplanting and second at the time of maximum flowering and fruit set. The results revealed that tomato intercropped with mustard at 2:1 ratio had recorded reduced incidence of whitefly and thrips population and fruit borer damage as well in two different field studies. Natural incidence of tomato spotted wilt virus (TSWV) and leaf curl virus (LCV) diseases were noticed on the rainfed tomato crop raised during August-September, 1999 planting season. The incidence of TSWV and LCV diseases were less under intercropped tomatoes than sole crop tomato and this was significantly low on the mustard intercropped plots. Nearly 30% of plants were lost due to these diseases in the tomato sole crop plots and this loss in plant population was nearly 45-60% more than the mustard intercropped plots. The combined yield of undamaged and damaged fruits was 16.319 t ha^{-1} and 16.028 t ha^{-1} for the sole tomato and mustard intercropped tomato under irrigated condition. However, under rainfed condition due to the severe incidence of viral diseases, an yield of 5.832 t $ha^{-1}$was recorded in sole crop while it was 8.527 t ha^{-1}_in mustard intercropped plots. The undamaged fruit yield recorded was 15.00 and 7.810 t ha^{-1} for the mustard intercropped plots, whereas it was 13.386 and 4.833 t ha^{-1} for sole crop tomato under irrigated and rainfed conditions respectively. The mustard intercropping had given an additional net return of Rs.7080 and Rs.12400 because of reduced pest infestation under irrigated and rainfed conditions respectively.

Vegetables are indispensible for healthy nutrition and thus gains importance. Tomato, *Lycopersicon esculentum* Mill. is one such important vegetable crop commercially grown worldwide. It is raised both as an irrigated and rainfed crop in India and particularly in TamilNadu. The average productivity of tomatoes in India is still 9.78 t ha^{-1} as against world average of 23.51 t ha^{-1} (Bose *et al*, 1993). Vulnerable to pests, the crop is known to be infested by an array of insect pests, of which sucking pests *viz.* thrips, *Thrips tabaci* (Genn.), whitefly, *Bemisia tabaci* (Genn.) and fruit borer, *Helicoverpa armigera* (Hub.) are considered to be important. The use of highly toxic insecticides, though a cheap source of pest control, is considered not only injurious to living organisms but leads to serious ecological disturbances in the agroecosystem on long term approach. Further, pesticide free produces are gaining importance both in the inland and foreign markets. Intercropping is believed to be a vital field tool that minimises pest population in any

Table 1. Incidence of fruit borer damage on irrigated tomato under different intercropping and pesticide application

Factor	Percentage fruit damage at different intervals																		
	60 DAP				75 DAP				90 DAP				105 DAP				120 DAP		
	C_1	C_2	C_3	M	C_1	C_2	C_3	M	C_1	C_2	C_3	M	C_1	C_2	C_3	M	C_1	C_2	C_3	M
I_1	4.3	3.3	8.2	5.3	7.0	5.1	12.0	8.0	10.7	10.8	16.4	12.6	8.8	9.8	11.6	10.1	6.8	6.2	8.2	7.1
I_2	3.9	2.9	5.5	4.1	4.9	3.7	7.0	5.2	7.6	6.6	8.5	7.6	7.2	6.4	8.2	7.3	4.9	5.2	6.5	5.5
I_3	5.3	3.9	8.3	5.8	7.9	5.8	13.7	9.2	12.1	12.5	16.8	13.8	10.6	10.1	12.0	10.9	7.4	7.1	8.7	7.7
I_4	5.1	3.9	9.4	6.1	7.9	6.5	16.6	10.3	15.7	12.9	17.8	15.5	11.8	10.6	12.4	11.6	8.7	8.2	9.2	8.7
Mean	4.6	3.5	7.9		7.0	5.3	12.3		11.5	10.7	14.9		9.6	9.2	11.1		7.0	6.7	8.1	
Factor		SEd	CD			SEd	CD			SEd	CD			SEd	CD			SEd	CD	
I		0.28	0.58			0.44	0.92			0.61	1.27			0.43	0.89			0.31	0.65	
C		0.24	0.50			0.38	0.79			0.53	1.10			0.37	0.77			0.27	0.56	
I x C			0.48	1.00			0.77	1.59			1.06	2.20			0.74	NS			0.54	NS

DAP- Days after planting
I - Intercropping; C - Chemical spraying; M – Mean; NS – Non-significant.
I_1 - Tomato + clusterbean; I_2 - Tomato + mustard; I_3 - Tomato + greengram; I_4 - Tomato sole crop.
C - NSKE 5% spray; C_2 - Monocrotophos 0.07% spray; C_3 - Untreated check.

Table 2. Effect of different intercropping systems on the occurrence of tomato spotted wilt virus (TSWV) and leaf curl virus (LCV) diseases on tomato

Factor	Percentage plants expressing disease symptoms at indicated days after planting (DAP)																			
	TSWV*								LCV											
	60 DAP				90 DAP				30 DAP				60 DAP				90 DAP			
	C_1	C_2	C_3	M	C_1	C_2	C_3	M	C_1	C_2	C_3	M	C_1	C_2	C_3	M	C_1	C_2	C_3	M
I_1	3.7^{b}	3.0^{b}	7.3^{ab}	4.7^{b}	11.2^{ab}	9.5^{b}	14.0^{ab}	11.6^{b}	0.5^{a}	0.5^{a}	0.2^{a}	0.4^{a}	6.0^{b}	4.0^{c}	8.4^{ab}	6.1	9.7^{ab}	8.2^{b}	9.2^{c}	9.0
I_2	1.5^{c}	0.9^{c}	5.3^{b}	2.5^{c}	7.8^{b}	6.9^{b}	10.3^{b}	8.3^{c}	0.3^{a}	0.2^{a}	0.3^{a}	0.3^{a}	5.4^{b}	5.2^{bc}	5.7^{c}	5.42	8.3^{b}	7.3^{b}	8.3^{c}	8.0
I_3	4.6^{b}	3.0^{b}	5.6^{b}	4.4^{b}	12.8^{a}	10.4^{b}	12.2^{b}	11.8^{b}	0.3^{a}	0.4^{a}	0.5^{a}	0.4^{a}	7.0^{b}	6.6^{ab}	7.3^{b}	7.0	10.1^{ab}	10.0^{a}	11.7^{b}	10.6
I_4	7.4^{a}	5.5^{a}	8.9^{a}	7.3^{a}	16.0^{a}	17.3^{a}	19.0^{a}	17.4^{a}	0.4^{a}	0.1^{a}	0.4^{a}	0.3^{a}	8.8^{a}	7.7^{a}	9.2^{a}	8.6	11.0^{a}	10.6^{a}	15.7^{a}	12.4
Mean#	4.3^{b}	3.1^{c}	6.8^{a}	4.7	12.0^{ab}	11.0^{b}	13.9^{a}	12.3	0.4	0.3	0.4	0.3	6.8	5.9	7.7	6.8	9.8	9.0	11.2	10.0

(Data analysed after arcsin transformation)
* Interaction between I and C was non significant
# Mean significance is indicated by letters both in column and row by DMRT
In a column, data followed by a common letter are not statistically significant by DMRT at p= 0.05.

given agroecosystem (Arnon, 1975; Altieri and Letourneau, 1982; Andow, 1991 and Theunissen, 1994). Hence, to manage the different insect pests of tomato using cropping system approach, a study was performed to assess the utility of commonly tried intercrops with tomato aimed at ecofriendly pest management strategies with reduced insecticide usage and crop diversionary approach.

Materials and methods

Field trials were laid in a factorial randomised block design (FRBD) during 1998-2000 at the Regional Research Station, TamilNadu Agricultural University, Paiyur located in the North-Western Zone of TamilNadu, which is an important zone of tomato cultivation both under rainfed and irrigated conditions. Tomato *Cv.* PKM 1, was raised as an irrigated crop during June-July, 1998 and rainfed crop during August-September, 1999 planting seasons. Crops *viz.*, cluster bean,*Cyamopsis tetragonoloba* (L.) Taub. (*Cv.* Pusa cluster), green gram, *Vigna radiata* (L.) (*Cv.* Paiyur 1), and Indian mustard, *Brassica juncea* (Czen and Coss) (*Cv.* Seetha), were undersown as intercrops after every second row of tomato in a 2:1 ratio along with the transplanted seedlings of tomato in ridges and furrows of 75 x 30 cm spacing. The intercropping systems were compared with the tomato sole crop.

Two rounds of spraying of plant product, neem seed kernel extract (NSKE) 5% and insecticide, monocrotophos 0.07% were imposed in the different intercropped plots once during a month after transplanting and second at the time of maximum flowering and fruit set. The intercrops were not sprayed with the chemicals.

Observations were recorded on ten randomly selected plants per treatment per replication for the incidence of insect pests by counting the number of adults plus nymphs per compound leaf for whiteflies; per compound leaflet for thrips at 30, 45 and 60 days after planting(DAP). The *in-situ* leaf counts were made on compound leaves representing the top, middle and bottom of plant canopy along the main stem and averages were worked out. The fruit damage caused by fruit borer was assessed as percentage fruit damage at 60, 75, 90, 105 and 120 DAP. Yield of main crop was recorded as undamaged and damaged fruits separately at each harvest. In the rainfed crop, the natural occurrence of tomato spotted wilt virus (TSWV) disease transmitted by thrips and leaf curl virus (LCV) disease transmitted by whiteflies were recorded by counting the number of plants in individual plots with typical symptoms for TSWV at 60 and 90 DAP and for LCV at 30, 60 and 90DAP and expressed on percentage basis. The values obtained were subjected to angular transformation and analysed statistically.

Results and discussion

The risks due to diseases, pests and climatic factors are reduced in intercropping (Arnon, 1975). Diversification of crop ecosystem in many cases results in reduced pest infestation (Altieri and Letourneau, 1982). The preliminary investigations made during the study revealed that crops *viz.* clusterbean, mustard and green gram reduced the incidence of pests of tomato than the intercrops *viz.* onion, soybean and coriander. Detailed investigations revealed that tomato under irrigated and rainfed situations recorded reduced incidence of sucking pests *viz.* whiteflies (Fig.1), thrips (Fig.2), and fruit borer (Table 1, Fig. 3) damage when intercropped with mustard, which was closely followed by clusterbean and greengram. The plant product NSKE 5% and monocrotophos 0.07% also reduced the incidence of thrips and whiteflies significantly, when compared to the untreated plots. Significant interaction effects were also noticed between intercropping and chemical spraying.

In general, employing intercropping system results in reductions of insect pest populations sufficiently large enough to obviate pesticide applications (Theunissen, 1997). In the present study, at various stages of crop growth, in mustard intercropped non-sprayed plots (I2 X C3) the population of whiteflies and thrips and fruit borer damage (Table 1) were nearest to chemical treated, mustard intercropped plots (I2 X C1 and I2 X C3). In the non-sprayed tomato sole crop plots (I4 X C3), the population of whiteflies and thrips were almost double as that of I2 X C3 plots. Intercropping influences the immigrating insects in such a way that crop colonisation is delayed and thus lower population levels of these species are found in the intercropped vegetables (Costello, 1995). Intercrops may emenate volatile or redolent compounds which might be influencing the feeding and breeding behaviour of main crop insects (Phillipps, 1977). Interestingly, in certain cases the foliage density of intercrops could affect the mobilty of invading insects (Tahvanainen and Root, 1972). The altered micro climate (Lockwood et al., 1979) and increased natural enemy population under intercropped situations (Chelliah and Gunathilagaraj, 1993) have negative impact on the pest population of main crop. Host plant quality is affected by the presence of intercrops in such a way that the insects cease to feed and reproduce (Harrewijn

Table 3. Effect of different intercropping on fruit yield (t ha^{-1})of tomato

Factor	Yield t ha^{-1}															
	Irrigated								Rainfed							
	Healthy fruits				Damaged fruits*				Healthy fruits				Damaged fruits*			
	C_1	C_2	C_3	M	C_1	C_2	C_3	M	C_1	C_2	C_3	M	C_1	C_2	C_3	M
I_1	13.800^b	14.167^b	10.700^b	12.889	1.033^c	0.883^c	1.800^b	1.239^c	6.733^a	7.267^a	6.233^{ab}	6.744^b	0.900^a	0.850^a	1.100^a	0.950^a
I_2	15.833^a	16.100^a	13.067^a	15.000	0.850^c	0.800^c	1.433^b	1.028^c	7.767^a	8.380^a	7.283^a	7.810^a	0.667^b	0.617^{bc}	0.867^b	0.717^b
I_3	11.400^c	12.133c	10.433^b	11.322	1.833^b	1.450^b	1.967^b	1.750^b	5.050^b	5.267^b	5.185^b	5.167^c	0.577^b	0.563^c	0.847^b	0.662^b
I_4	13.057^b	14.300^b	12.800^a	13.396	2.633^a	2.367^a	3.800^a	2.933^a	5.200^b	5.567^b	3.733^c	4.833^c	1.023^a	0.800^{ab}	1.173^a	0.999^a
Mean	13.523	14.175	11.750	13.149	1.588	1.375	2.250	1.738	6.188	6.620	5.608	6.139	0.792	0.702	0.997	0.832
Factor		SEd	LSD 5%			SEd	LSD 5%			SEd	LSD 5%			SEd	LSD 5%	
I		0.424	0.954			0.262	0.584			0.321	0.665			0.103	0.213	
C		0.403	0.855			0.260	0.551			0.278	0.576			0.059	0.123	

*Interaction between I and C was non significant

In a column, data followed by a common letter are not statistically significant by DMRT at p= 0.05.

Table 4. Effect of intercropping on economic returns of tomato production (CFR)

Cropping system	Fruit yield (t ha^{-1})				Increase or decrease in yield over sole crop	Increase or decrease in monetary returns over sole crop (Rs.)*	Returns from intercrop (Rs.)	Net increase in returns over sole crop (Rs.)
	Healthy	Damaged	Total	Ratio				
Irrigated crop								
Tomato + Clusterbean (2:1)	12.889	1.239	14.128	8.8	-0.497	-1988	2672	684
Tomato + Mustard (2:1)	15.000	1.028	16.028	6.4	1.614	6456	624	7080
Tomato + Green gram (2:1)	11.322	1.750	13.072	13.4	-2.064	-8256	1900	-6356
Tomato sole crop	13.386	2.933	16.319	18.0				
Rainfed crop								
Tomato + Clusterbean (2:1)	6.744	0.950	7.694	12.3	1.911	7644	2236	9880
Tomato + Mustard (2:1)	7.810	0.717	8.527	8.4	2.977	11908	492	12400
Tomato + Green gram (2:1)	5.167	0.662	5.829	11.4	0.334	1336	1200	2536
Tomato sole crop	4.833	0.999	5.832	17.1				

*Price of tomato was taken as Rs. 4.00 per kg

Fig.1 Incidence of whitefly, *B.tabaci* on tomato under different intercropping systems

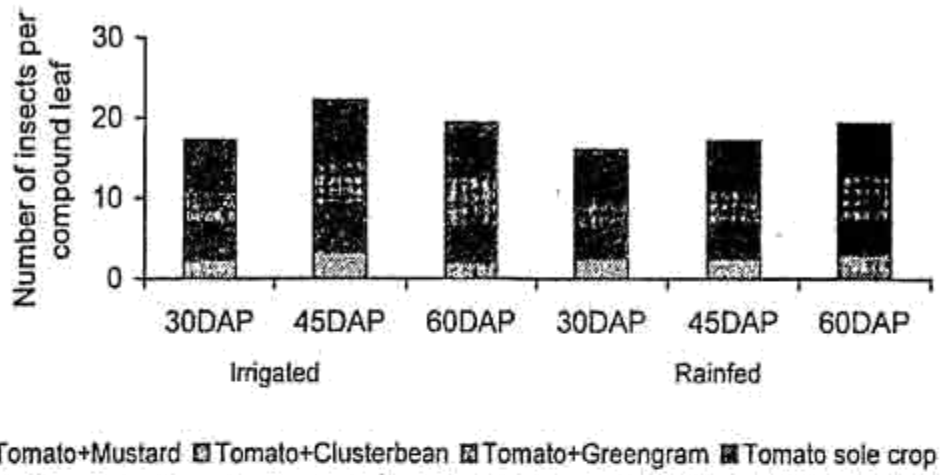


Fig. 2 Incidence of thrips, *T. tabaci* on tomato under different intercropping systems

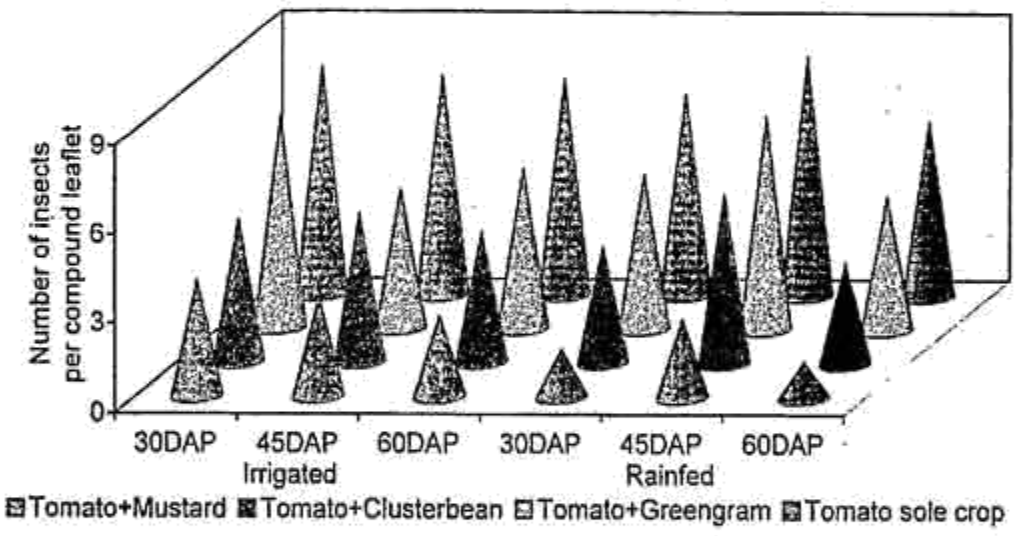
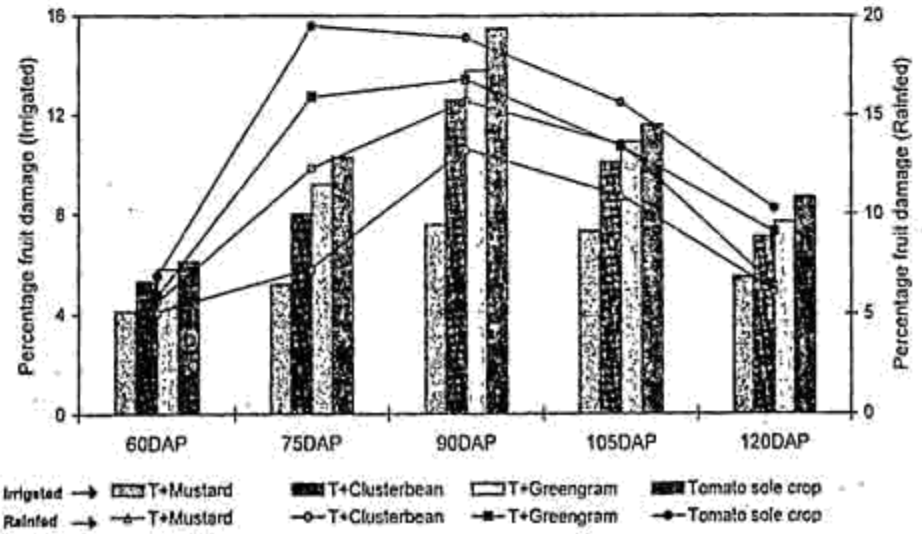


Fig. 3 Influence of intercropping systems on the fruit borer incidence on tomato



et al., 1996). Many of these effects lead to situations in which the use of pesticides to grow good quality vegetables can be minimised.

Intercropping with mustard also greatly reduced the occurrence of tomato spotted wilt virus (TSWV) and leaf curl virus (LCV) diseases, which was observed on tomato raised as rainfed crop during August - September, 1999. The data recorded on TSWV at 60DAP and 90DAP indicated that the mustard intercropped plots recorded 2.54 and 8.34 per cent plants with the symptom while the tomato as sole crop recorded 7.26 and 17.43 per cent respectively. The other two intercropping systems also recorded reduced level of disease incidence when compared to the tomato sole crop system. In the case of LCV disease, the data recorded at 30, 60 and 90 DAP indicated that the plants with disease symptom were significant at 60 and 90 DAP. The mustard intercropped plots recorded 5.42 and 7.97 per cent plants with the LCV symptom while the sole crop plots were with 8.59 and 12.44 per cent disease incidence at 60 and 90DAP respectively (Table 2) This might be due to the reduced activity of insect vectors under intercropped situations.

The yield recorded revealed that the mustard intercropped plots recorded a mean fruit yield (healthy) of 15.00 t ha^{-1} under irrigated condition and 7.810 t ha^{-1} under rainfed condition, whereas the tomato sole crop system recorded 13.386 and 4.833 t ha^{-1} under irrigated and rainfed conditions respectively. The maximum quantity of damaged fruits due to fruit borer damage was noticed with the sole crop system, which had recorded 2.933 and 0.999 t ha^{-1} under irrigated and rainfed conditions respectively (Table 3). However, when both the damaged and undamaged yields were combined together, the sole crop and mustard intecropped tomato recorded 16.319 and 16.028 t ha^{-1} under irrigated condition. But, the situation was different under rainfed condition, where the combined yields was 5.832 and 8.527 t ha^{-1} for sole and mustard intercropped tomato (Table 4). This is because of the loss of nearly 30 per cent plant population with little or no yield due to the severe incidence of TSWV and LCV diseases in the sole crop plots under rainfed condition. At Dharmapuri district growing mustard along the borders of tomato crop is a common practice among the farmers. Introduction of mustard as an intercrop in tomato would greatly reduce the problems of key pests like whiteflies and thrips which serve as vectors for the LCV and TSWV respectively. In addition, the fruit borer damage also got reduced under mustard intercropping situations. Increased net returns were also noticed (Rs.7080 and Rs.12400) because of reduced fruit borer incidence and reduced disease infection under mustard intercropping. Though the intercropped plants compete each other for resources leading to yield losses than monocrops, the quality and marketable weight are taken consideration, the intercropping is a serious alternative for monocropping.

For vegetables, quality is the first parameter which determines the yield in most markets. Increased external quality because of low pest infestation is one aspect of quality and the added innate quality by growing vegetables under no or less pesticide usage is the another. Further, sustainable methods such as intercropping would get significance in areas of public health issues concerning pesticide residues on vegetables. Tomato is an important vegetable crop being not only used for culinary purposes within the country but also being exported to other countries. Residues of pesticides used for the management of the fruit borer at the fruit maturity phase may pose serious hurdles in exports. Hence, production of tomatoes using intercropping systems with less or no pesticides would fetch better prices in the external markets. If the consumers were prepared to pay for such an added quality the growers would take the risk in production costs. Modern agriculture aims at profits by reducing production costs. It is evident from the present study that intercropping tomato with mustard would reduce the number of insecticide sprayings because of less insect pest infestation, thereby reduce the cost of cultivation. Modern agriculture aims at profits by reducing production costs. In addition, eventhough there is any reduction in yield because of intercropping mustard in tomato, that may be compensated by the reduced pest made loss and increased quality of the produce.

Hence, it is concluded that intercropping tomatoes with mustard in a 2:1 ratio would reduce the key insect pests incidence on tomato and thereby reduce the insect related losses to the farmers.

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Thermogravimetric analysis of paddy straw

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Abstract : Results of the studies on thermogravimetric analysis (TGA) of raw and IN HCl acid treated ground paddy straw revealed that thermal degradation takes place in three main stages of mass loss, namely (1) removal of moisture (2) removal of volatile matter and (3) oxidation of fixed carbon. The rate of removal of volatile matter was faster in the untreated sample than that in the acid treated sample. But the rate of removal of fixed carbon was faster in acid treated paddy straw than that untreated paddy straw. Temperatures of above 340 and 375oC are required to remove fixed carbon from raw and IN HCl treated paddy straw to get amorphous silica. Hydrochloric acid leaching of paddy straw at 75oC for one hour prior to combustion is necessary for production of ash of milky white colour. *(Key Words:* Paddy Straw, Thermogravimetric Analysis, Ash, Silica)

Paddy crop being one of the major cereal crops of the world produces major byproduct, namely, paddy straw. It is estimated that India produces about 120 million tons of paddy straw every year (Sarnpathrajan et al., 1999). Paddy straw with a low bulk density (25.42 kg/m^3) (Kaleemuflah, 1988) and high silica content has some traditional use as cattle fodder. Paddy straw, a fibrous material, therefore, poses disposal problems wherever it is produced in excess. However, in recent years, as the concept of 'converting waste into wealth' became more popular, serious research work is in progress to use the paddy straw in a meaningful way. The suggested uses