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Parasitism of Striga lutea Lour. on Rice and methods to protect rice plant against Striga.

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Introduction: There is a fair amount of literature on *Striga* as a root parasite on several agricultural crops. Luthra (1921) in the course of his studies of *Striga densiflora* Benth. on sugar-cane makes mention of *Striga lutea* Linn .as a root parasite on Jowar *(Andropogon Sorghum* Brot.*)* In the case of *Striga densiflora* he thinks that the parasite absorbs the food materials from the soil as a normal course to elaborate its own food while being parasitic on the host's roots. He has threfore classed it as a typical semiparasite. Mechanism of absorbing food material from the host plant and the anatomy of haustoria etc., are described and illustrated by the same author. Thadulingam and Narayana (1932) mention *Striga lutea* as attacking Varagu *(Papsalum Scrobiculatum* Linn.*)* Ragi *(Eleusine Coracana* Gaertn.*)* and Sugarcane *(Sacharum officinarum* Linn. The same authors have recorded *Striga euphrasioides*, Benth. another species of *Striga* attacking rice plants in the swamp. In the brochure issued by the Imperial Council of Agricultural Research (16). *Striga lutea* is mentioned as a serious pest on Tenai or Korra *(Setaria Italica* Benth*)*. Pearson (1913) has made an extensive study of *Striga lutea* L. as a parasite on maize. Excepting some casual reference made of its parasitism on rice by a few authors, very little detailed work has been done on it.

Burning, uprooting and growing trap crops have been generally advocated by different authors as cheap and practical methods of control against striga. In his trials with various chemicals to eradicate this weed, Pearson (l. c.) found that sodium chloride and potassium nitrate reduced the infection of striga. Burning of rubbish on the field after harvest wherever this is possible is advocated by this author although he admits that the benifit is very limited. Growing trap crops and ploughing them up successively for two or three years as a measure to reduce the loss on account of this parasite to a minimum, is also suggested by the same author. Sudan grass (Gray, 1932) has been reported to be used as a trap crop. The fact that *Striga lutea* cannot thrive under swampy conditions is made use of in eradicating this parasite on sugarcane. At the Indian Sugar Cane Station, Coimbatore, fields where striga is known to attack canes are now and then puddled to get over the trouble. But in the Malabar Coast of Madras where rice is grown as a dry (rainfed) crop on the slopes of hills (*modan* lands) puddling fields is impracticable.

Realising the importance of *Striga lutea* to the dry rice crop of Malabar and the very scanty scientific information available about the parasite, the author undertook the present study of the parasite in several aspects in relation to rice.

Material and methods.

(1) *Striga in relation to the host:* To study the habits of *Striga lutea* in its relation to the host and incidentally to the neighbouring weeds, the following simple experiments were conducted in an infected field cropped with rice. A striga infested area was divided into a number of compartments and each compartment was subjected to different treatments as below:

Compartment No. 1. All the striga plants were removed along with their roots as well as the hosts (rice plants) and other weeds, chief of them being *Borreria hispida* K. Sch. No striga appeared again in this area.

Compartment No. 2. The host plants were retained after rooting out all the striga plants. On the third day fresh batches of striga appeared, evidently they being new and separate ones that were preparing to come out.

Compartment No. 3. The hosts and the parasites were removed leaving only the weeds which included several species of grasses. No striga came out.

Compartment No. 4. The host plants were cut below their root junctions. All the striga plants and also other weeds were removed. On the third day new striga came up as in No. 2, but began to wilt in less than a week.

Compartment 5. In this the above experiment was repeated but the striga plants were retained. Before the lapse of a week the striga plants began to wilt and in another 5 days all of them were dead

The following conclusions might be drawn from the above observations. (i) each and every plant is not a host for this root parasite, (ii) that weeding affords only a partial relief to the host plant against this parasite and (iii) that even during the later stages of the parasite when it has functioning green leaves etc., it cannot survive without the host.

(2) *Striga in relation to water:* Clumps of *Striga lutea* "in situ" with their host plants were bodily transplanted into the swamp rice area with water running 5 to 6 inches deep. The parasite did not survive for more than 3 days although the host plants took root and thrived.

(3) *Striga in relation to the host and the season:* In a field known to be infected with striga rice was sown periodically at 15 days intervals begining from 13th May 1936 and the time of appearance of the parasite was noted in the respective plots. The statement below gives the data collected about the interval of time between the sowing of rice and the appearance of the parasite above ground level.

Date of sowing rice	The date on which the 1st plant of *Striga* appeared above ground	Period in days between the sowing of rice and the appearance of *Striga*
13—5—36	24—6—36	41
28—5—36	28—6—36	30
12—6—36	18—7—36	35
27—6—36	2—1—36	35

It is seen from the above that for all the sowings of rice on or before the end of May, striga appears only by the end of June while it was observed that this appeared in larger numbers with the begining of July and thereafter. Heavy showers intermittent with bright spells of sunlight which are characteristic of this month appear to be very favourable to an outbreak of striga. Heinricher (1910) has said that most of the root parasites of the same group as striga are sun-loving plants. Again it will be observed that sowing on the 28th of May brought forth striga exactly after a month. This interval of 30 days between the sowing and the first appearance of striga above ground is, more or less, kept up for all the sowing coming after the 28th May.

The limiting factor to the incidence of striga seems to be primarily the season besides proper age and development of the host plant.

Pearson (l. c.) found that an acid medium is favourable for the germination of the striga seed and that the germination is greatly controlled by the physical condition of the soil. In a pot culture experiment, conducted by the writer, it was observed that seeds of striga germinated when kept in contact with the absorptive region of the root and never when kept away from it, thus confirming that the absorptive region of the root alone exuded certain stimulating substance necessary for its germination and necessarily acidic in nature (Dyer, 1894). In the present studies, it looks that only a month or more old rice plant is able to secrete this stimulating substance and this, under certain favourable conditions of the soil attained by the onset of the South West monsoon in June with abundant rains and occasional bright sunshine, perhaps, induces the free germination of the striga seed.

This one month period might however get extended determined by the state of development in the host. For instance, we note for the sowing on 12th. June in table I that the time taken for the striga to appear has exceeded the minimum period by 6 days. It may be mentioned in passing that this batch was handicapped in the early stage of growth by deficit rains at the time of sowing (Graph I). Subject to a minimum of 30 days in the age of the host, an early and quick growth of the host plant favours an early onset of striga. Evidently, rice which has completed 30 days by July stands to suffer equally badly as rice sown any time after June. Therefore any significant reduction in the yield of rice with later sowings cannot be attributed entirely to the effect of striga. This on the other hand, may be due to the combined effect of the parasite and the depleted vitality of the host on account of the sowings made in the midst of the increasing rains after June. Graph I gives an idea of the distribution of the rains recorded during this period of the experimentation. It would appear therefore that a crop being over 30 days of age before July is somewhat of an insurance against its succumbing to the parasite. In other words, in cropping the infected fields rice sown earlier than May with the help of the premonsoon showers contrary to the practice of the ryots should yield better than later sowings.

That early sowings contribute to increased yield is evident from the data collected at the station. In the *modan* area free from this parasite, the yield of rice when sown in the month of April gives as an average of 4 years an acre yield of 839 lb. of grain against an average yield of 642 lb. when sown late in May. In one year (17) a particular variety of rice when sown early in April gave an acre yield of 858 lb. while the same variety gave only 347 lb. when sown late in May. It must, however, be understood that early or late sowings which bring about differences in yield cover only a short period of time. The middle of May may be taken as the maximum limit for late sowings capable of producing differential effect on yield, while sowings done beyond that do not influence the yield.

The ordinary practice with the ryots is to sow rice, more or less, with the commencement of the regular monsoon. It is clear then, that by sowing so late as with the monsoon, the young rice crop is unable to make full use of all the benefits accruing from the earlier rains. The non-availability of the earlier opportunities therefore constitute a definite loss to the growth and development of rice, when this is sown late. The effect of the season on the yield will therefore be seen when rice is sown sufficiently early with the pre-monsoon showers which though scanty at times are more than sufficient to nurture a young crop of rice through their nursery stage. Graph II gives us a fair idea of the distribution of rains in this tract during the time of *modan* cultivation.

That the crop is benefitted by early sowing not only in fields free from striga but also in the striga infected fields was apparent from the yield data of the station during three seasons 1933—1935 (17).

(4) *The degree of protection against Striga by early sowing:* In order to study this rice was sown in an infected field at four different times starting early in the season at definite intervals of 15 days. Taking advantage of a small shower, before the onset of the monsoon, the sowings were done on the 13th and 28th of May, 12th and 27th of June 1936, respectively. The four sowings were randomised into each of four blocks comprising the experimental area. Thus on the whole there were four repetitions for each sowing. Each replication consisted of a single plot 29′ long and 5′ wide. In order to obtain a more uniform and intensive

infection of the soil, each time just before sowing rice, the seeds of striga collected during the previous year were broadcasted in all the four replications at the rate of 1 oz. per cent. The seed was mixed with sand to ensure uniform distribution. In sowing rice, three to four seeds were dibbled in a hole, 4 inches apart in furrows running with the length of the plot. There were 12 such furrows for every plot.

To assess the seasonal influence apart from that due to the parasite, an exact replica (control) of the above sowings was carried out in a non-infected field. A month after sowing, the plants in both the infected and the control area were thinned leaving only 2 seedlings per hole. Fortnightly measurements for the height of plants from sowing to earing were taken for all the sowings commencing 15 days after sowing Heights were measured for 75 plants taken at random from each of the four replications, totalling on the whole 300 plants for each sowing. The average and mean heights of 75 plants for each replication under each date of measurement are presented in tables I and II. Mean heights of 300 plants for the different dates of measurements under each sowing for both the infected as well as the control areas are plotted in the graph I. The dotted lines represent the control. A comparison between the growths of rice in the infected and the control area clearly indicates that all the four batches of sowings in the latter despite being sown at different periods of the season exhibit identical growth for both rate and total growth. The yields from the infected and the control area were statistically analysed and the details of analysis are given in the statements III to XIV. It will be seen that there is practically no difference in the grain yields for the first three batches of sowings in the non-infected area while there is a sudden drop in the yield for the last batch (Table III). The unnaturally low yield of grain in the fourth sowing for both the infected as well as the non-infected areas (Tables III and IX), explained under 'Parasitism and the time of reproduction of striga' (see below) therefore accounts for the significance satisfying the 'Z' test in Table IV. It will, however, be noted that leaving out the last sowing, the difference between no two sowings in the control exceeds the critical difference (Table V), nor is this significant in their straw yields (Tables VI, VII and VIII). On the other hand, the difference in yield in the infected plot (Tables IX to XIV) is found to be highly significant thus proving that the superior performance of the earliest over the later sowings (Tables XI and XIV) in the infected area is not so much due to any seasonal influence as to a successful escaping of the early sown crop from the striga attack explained under striga in relation to the host and the season ". This freedom for the earliest sown crop from striga would be further clear from the similarity of growth which this sowing alone bears to the normal growth of rice in the control (Graph I). The amount of difference above the critical difference, may be an index to the degree of protection conferred on rice against an attack by this parasite.

TABLE I.

(Showing average figures for four replications)

Date of sowing rice.	Dates of measurement										Mean	S.D.	Coefficient of variation
	28—5—36	12—6—36	27—6—36	12—7—36	27—7—36	11—8—36	26—8—36	10—9—36	25—9—36	10—10—36			
13—5—36	6·55	7·93	13·20	16·90	17·70	19·73	23·13	...	...	...	15·02	5·65	37·61
28—5—36	...	4·93	7·28	11·08	12·78	13·45	15·80	18·95	...	...	12·04	4·44	36·87
12—6—36	...	...	5·95	7·90	9·33	10·58	11·40	14·70	15·95	...	10·83	3·29	30·37
27—6—36	...	...	...	5·68	7·90	8·30	10·95	13·78	14·18	15·60	10·91	3·46	31·71

TABLE II

13—5—36	6·73	8·10	11·50	15·78	16·50	17·03	20·65	...	...	...	13·76	4·84	35·17
28—5—36	...	5·13	6·93	9·50	10·75	15·43	20·60	21·08	...	...	12·77	5·91	46·28
12—6—36	...	...	5·85	7·65	9·33	15·10	19·15	20·03	20·75	...	13·98	5·83	41·70
27—6—36	...	...	...	6·28	7·95	13·65	18·18	20·05	20·58	21·28	15·42	5·76	37·35

TABLE III

Area of a single strip — ⅓ cent — Grain yield in ¼ oz — control

Blocks	Treatments: Dates of sowing 3-5-36	28-5-36	12-6-36	27-6-36	Total	Mean yield
1	39	42	39	19	139·0	34·75
2	37	35	38	19	129·0	32·25
3	34	33	30	25	122·0	30·50
4	35	37	34	15	121·0	30·25
Total	145	147	141	78	511·0 Grand total	
Mean yield	36·25	36·75	35·25	19·50		31·93 General mean

TABLE IV

Analysis of Variance

Due to	Degrees of freedom	Sum of squares	Mean square	½ log e (Mean sq.)
Blocks	3	51·69		
Treatments	3	829·69	276·56	2·8112
Error	9	109·56	12·17	1·2495

1% point for 'Z' ... ... 0·9724.
Observed value of 'Z' ... ... 1·5617.
Hence significant.

TABLE V

Particulars	Treatments: Dates of sowing 13-5-36	28-5-36	12-6-36	27-6-36	General mean	S.E. of mean difference	'Z' test satisfied or not P=0·01	Critical difference P=0·05
Mean yield in ¼ oz.	36·25	36·75	35·25	19·5	31·94			
% on general mean	113·49	115·06	110·36	61·05	100·00	7·71	Yes	17·44

TABLE VI

Area of single strip ⅓ cent — straw yield in ¼ oz. — control

Blocks	Treatments: Dates of sowing 13-5-36	28-5-36	12-6-36	27-6-36	Total	Mean yield
1	253	269	286	254	1062	265·50
2	247	267	269	258	1041	260·25
3	267	232	245	245	989	247·25
4	261	216	269	224	970	242·50
Total	1028	984	1069	981	4062 Grand Total	1015·50
Mean yield	257·00	246·00	267·25	245·25		253·875 General mean

TABLE VII

Analysis of Variance

Due to	Degrees of freedom	Sum of squares	Mean square	½ log e (Mean sq.)
Blocks	3	1396·25	465·416	
Treatments	3	1300·25	433·416	0·7333
Error	9	2445·25	271·69	0·4997

5% point of 'Z' ... ... 0·6757.
Observed value of 'Z' ... ... 0·2336.
Hence not significant.

TABLE VIII

Particulars	Treatments — Dates of sowing 13—5—36	28—5—36	12—6—36	27—6—36	General mean	S. E. mean difference	'Z' test satisfied or not (P=0·05)	Critical difference (P=0·05)
Mean yield in ¼ oz.	257·00	246·00	267·25	245·25	253·87			
% on general mean	101·23	96·90	105·27	96·60	100·00	4·59	No	10·38

TABLE IX

Single strip area—⅕ cent—Grain yield in ¼ oz—Infected field

Blocks	Treatments — Dates of sowing 13—5—36	28—5—36	12—6—36	27—6—36	Total	Mean yield
1	89	43	23	6	161	40·25
2	113	41	17	8	179	44·75
3	89	37	16	6	148	37·00
4	117	41	21	9	188	47·00
Total	408	162	77	29	676	169·00
Mean yield	102	40·5	19·25	7·25		42·25 General mean

TABLE X

Analysis of Variance

Due to	Degrees of freedom	Sum of squares	Mean square	½ Loge (mean square)
Blocks	3	241·5	80·5	
Treatments	3	21308·5	7102·83	4·4341
Error	9	5010·0	55·66	2·010

1 % point for 'Z' ... 0·9724
Observed value of 'Z' ... 2·4241
Hence significant.

TABLE XI

Particulars	Treatments: Dates of sowing 13–5–36	28–5–36	12–6–36	27–6–36	General men	S.E. of mean diffe- rence	'Z' test satisfied or not (P= 0·01)	Critical diffe- rence (P= 0·05)
Mean yield in ¼ oz.	102·00	40·50	19·25	7·25	42·25	21·10		
% on general mean	241·42	95·86	45·56	17·16	100·00	12·48	Yes	28·23

TABLE XII

Single strip—⅓ cent—Straw yield in ¼ oz.—Infected field

Blocks	Treatments: Dates of sowing 13–5–36	28–5–36	12–6–36	27–6–36	Total	Mean yield
1	173	107	66	48	394	98·50
2	229	101	77	54	461	115·25
3	192	108	80	65	445	111·25
4	228	115	60	56	459	114·75
Total	822	431	283	223	1759	439·75
Mean yield	205·5	107·75	70·75	55·75		109·9375 General mean

TABLE XIII

Analysis of Variance

Due to	Degrees of freedom	Sum of squares	Mean square	½ log e (Mean sq.)
Blocks	3	735·69	245·23	
Treatments	3	54435·69	18145·23	4·9031
Error	9	1871·56	207·95	2·6686

1% point of 'Z' ... ... 0·9724.
Observed value of 'Z' ... ... 2·2345.
Hence significant.

TABLE XIV

Particulars	Treatments				General mean	S. E. of mean difference	'Z' test satisfied or not (P=0·01)	Critical difference (P=0·05)
	Dates of sowing							
	13—5—36	28—5—36	12—6—36	27—6—36				
Mean yield in ¼ oz.	205·50	107·75	70·75	55·75	109.84			
% on general mean	186·92	98·01	64·35	50·71	100·00	9·27	Yes	20·97

(5) ***Parasitism and the time of reproduction of striga:*** A scrutiny of graph I will throw some light into the inter-relation that exists between certain phases of growth in the life cycles of the host and the parasite. A close study of the life history of striga occurring in the ***modan*** lands showed that for an average striga plant from a seed lying in the top layer of the soil, it takes nearly 21 days from emergence on the surface of the soil to the opening of the first pair of the axillary flower buds. Normally the corolla sticks to the ovary for about 2 days and when it drops the next pair of buds immediately above open. From counts made for a number of plants, the total number of pairs of the flower buds per plant averaged 12. Thus it is seen that the flowering period extends to about 24 days. Adding to this a further period of 15 days from setting of the seed to the bursting of the capsule, the average life of a striga plant from appearance to the bursting of the last pair of the capsules runs to sixty days. This is the life span above ground for the majority of the striga plants occurring among the ***modan*** rice leaving those that live the major portions of their lives under ground. It has already been indicated that the incidence of striga is closely bound with the season and the age of the host plant. Putting the above two facts together the following table has been constructed to indicate the approximate dates on which striga is expected to appear, to put forth flowers and to develop pods for each of the four sowings. Against these are set the approximate dates of decline in the growth of rice under the different sowings as indicated by the growth curves (Graph I) in the infected fields and also the normal growth curves recorded from the control area.

TABLE XV

Dates of sowing rice	Date of 1st appearance of *Striga*	Expected date of appearance of *Striga*	Date of commencement of decline in the growth of host plant as indicated by the graph	Expected date of commencement of flowering in *Striga*	Date of partial recovery from the depression of growth in the host as indicated by the graph	Expected date of termination of the flowering period in *Striga*	No. of days by which the recovery is earlier than the date of termination of the flowering period in *Striga*
13–5–36	24–6–36	Last week of June	12–7–36	15–7–36	27-7–36	8–8–36	11
28–5–36	28–6–36	28–6–36	12–7–36	19–7–36	11–8–36	12–8–36	1
12–6–36	17–7–36	12–7–36	27–7–36	2–8–36	26–8–36	26–8–36	Nil
27–6–36	2–8–36	27–7–36	27–7–36 & 10–9–36	22–8–36	11–8–36 & 25–9–36	15–9–36	

The expected dates of flowering in striga has been calculated by adding 21 days to the date of its appearance above ground while it will be remembered that the average duration of *modan* rice from sowing to flowering is 10 days. On a scrutiny of the figures in the above table it will be seen that there is some agreement between the time of flowering of the parasite and the time of general decline in the growth of the host plant. In other words, the injury done to the host by the root parasite is at its worst when the latter enters its reproductory stage. Further, it is seen from the table that an early sown rice crop recovers from this depression occurring at the time of reproduction in striga very much earlier than a late sown one.

These varied phenomena in the growth of the host in relation to the root parasite under the different sowings have a close parallel to the yields of the different sowings (Tables XI & XIV). The low grain yield of the fourth sowing in the control as well as the infected area (Tables III & IX) in the same experiment could be partly attributed to a heavy infestation of the rice bug *(Leptocoriza aucta)* since these were the only strips of rice left in the whole area of the *modan* field and partly to the heavy showers at this period (Graph I) inducing some un-setting in the grain. The accepted principle among the ryots in these parts that *modan* rice should not be sown late in June as in this case has some significance. It is clear then that for the purpose of elucidating the information for which this experiment was designed, the last sowing is superflous and therefore might be ruled out.

To have an idea of the population of striga plants in the infected plot the number was counted in each of the plots at the time of harvest and tables XVI & XVII serve to show the degree of infection with striga, its distribution per rice plant and the percentage of visible striga plants to the number of seeds sown. Each replication was sown with 0·33 ozs. of striga seeds containing 13,67,815 seeds.

TABLE XVI

	Dates of sowing striga seed											
	13—5—36			28—5—36			12—6—36			27—6—36		
Repetitions	No. of Striga plants	No. of rice plants	Av. distribution of striga per rice plant	No. of striga plants	No. of rice plants	Av. distribution of striga per rice plant	No. of striga plants	No. of rice plants	Av. distribution of striga per rice plant	No. of striga plants	No. of rice plants	Av. distribution of striga per rice plant
1	3165	2112	1·5	3282	2112	1·5	2977	2112	1·4	1031	2112	0·5
2	3321	2112	1·6	3219	2112	1·5	2451	2112	1·0	1651	2112	0·8
3	4122	2112	1·9	3179	2112	1·5	2611	2112	1·2	975	2112	0·4
4	3341	2112	1·5	4021	2112	1·9	3031	2112	1·4	1112	2112	0·5
Total	13949	8448	6·5	13701	8448	6·4	11070	8448	5·0	4769	8448	2·2
Average	3487·2	2112	1·6	3425·2	2112	1·6	2767·5	2112	1·3	1192·2	2112	0·56

TABLE XVII

	Dates of sowing rice							
	13—5—1936		28—5—1936		12—6—1936		27—6—1936	
Repetition	No. of striga plants over ground	% of visible plants to seed	No. of striga plants over ground	% of visible plants over seed	No. of striga plants over ground	% of visible plants to seed	No. of striga plants over ground	% of visible plants to seed
1	3165	0·16	3282	0·18	2977	0·15	1031	0·06
2	3321	0·18	3219	0·17	2451	0·13	1651	0·09
3	4122	0·22	3179	0·17	2611	0·14	975	0·05
4	3341	0·18	4021	0·22	3031	0·16	1112	0·06
Total ...	13949	0·19	13701	0·18	11070	0·15	4769	0·06

TABLE XVIII

Treatments	1		2		3		4		5			
Dates on which counts made	Live striga plants before application of lime	Striga that died subsequent to the aplication	Live striga plants before application of lime	Striga that died subsequent to the application	Live striga plants before application of lime	Striga that died subsequent to the application	Live striga plants before application of lime	Striga that died subsequent to the application	Live striga plants before application of lime	Striga that died subsequent to the application	Live striga plants before application of lime	Striga that died subsequent to the application
I. Pot Sowings												
14—7—33	23	Nil	13	Nil	18	Nil	13	Nil	20	Nil	20	Nil
15—7—33	...	18	...	3	...	8	...	2	...	4	...	Nil
17—7—33	...	3	...	6	...	7	*1	1	*2	2	*1	Nil
19—7—33	...	1	...	2	...	1	*2	1	*2	1	*3	Nil
21—7—33	...	1	...	2	...	Nil	...	Nil	...	Nil	...	Nil
% death on the total live plants.		100%		100%		89%		25%		29%		Nil%
II. Field Sowings												
17—8—33	20	Nil	16	Nil	40	Nil	14	Nil	16	Nil	12	Nil
19—8—33	...	12	...	10	...	26	...	4	...	Nil	...	Nil
20—8—33	...	5	...	4	...	Nil	...	2	*1	Nil	*1	Nil
28—8—33	...	Nil	...	Nil	...	6	...	Nil	...	2	...	Nil
% death on the total live plants		85%		79%		80%		43%		11·7%		Nil%

* New arrivals after application of lime.

The low population of striga in the last sowing may be due either to bad germination of striga seed or to the germinated plants dying off due to the too wet conditions. The trials conducted at the station to study the habit of striga under the swampy condition and recorded elsewhere in this paper strengthens this view.

(6) *Protection of rice plant against* striga by: (i) *Weeding*: Systematic weeding before the parasite sets seeds carried on over a series of years might mitigate the trouble. But due to the small size of the seed, the large number produced and the capacity of the seed to remain dormant in the soil for long periods, it cannot be a complete success. Moreover, the soils in which the parasite occurs being poor in fertility, the yield of rice is usually low and it will not be an economic proposition to spend much money on weeding. (ii) *Employment of chemicals*: The efficacy of the following chemicals to destroy striga in all its stages of growth both above and under the soil without affecting the host plants, were tried taking into consideration the cost of the chemicals and the general resources of the average ryot.

(a) *Lime:* Burnt shell lime was tried both in the pot culture and in the field experiments. Rice plants about 2 months old growing in pots with the root parasites in all stages of growth were first treated with lime. The tabular statement below gives the doses of lime applied and the number of live parasites in the begining, the number of deaths and fresh ones coming through, daily for about a week. Cylindrical pots used in the experiment were filled with equal volumes of *modan* soil. The quantity of lime to be applied for each treatment was calculated for the surface area of the pot which measured 1 sq. ft. for each pot.

The treatments were—lime at lb. per acre: 1. 10,000, 2. 8,000, 3. 4,000, 4. 2,000, 5. 1,000, 6. Control—No lime. The first treatment was found to affect the rice plants causing some of them to wilt and die. That smaller doses of lime are not quite so efficacious in killing the parasite, is evident from the fact that in these treatments new striga plants did appear after the experiment was started. The same experiment was repeated in the infected field adopting identical doses over a 2 feet square area for each treatment. The lime was applied on 17—8—33. The results are tabulated below (table XVIII).

The results in the field experiments do not entirely agree with those of the pots though the trend is very similar. Even the maximum doses of 8 to 10,000 lb. of lime per acre which killed the striga completely in pots did not do so in the field. It was also noted that a crop, however, well treated against infection of striga with lime did not produce anything equal to the average yield from a non-infected crop. The results in the above experiments indicate that lime in doses of 4000—8,000 lb. per acre is almost fatal to the parasite killing over 80% of the population without appreciably affecting the host.

Economics of liming: 4000 lb. of lime would cost the ryot at the cheapest Rs. 20 (pre-war-rate). The net profit from an acre of non-infected *modan* rice will be not more than Rs. 15 for the prevailing price. It will, however, be remembered that an infected crop when treated with lime does not yield anything more than the average yield from a non-infected crop. Liming as a measure to eradicate striga is therefore un-economical.

(b) *Copper sulphate:* Copper sulphate solution was sprayed in 3 concentrations 1, 2 & 4 percent at 1000 c. c. of each over the surfaces of the soil in the pots (1 to 3) which were infected with striga. The sprayings were done on 17—8—1933. The observations are given below.

Dates of observations	(1) 1% solution	(2) 2% solution	(3) 4% solution
17—8—33	18 living striga plants. Host plants all healthy.	11 living striga plants. Host plants all healthy.	15 living striga plants. Host plants all healthy.
19—8—33	All striga plants scorched and 10 lodged. Host plants not affected.	All striga plants completely scorched and dying. Host plants partly affected.	Striga plants totally charred beyond recognition. Host plants badly scorched.
20 to 23—8—33	Host plants not affected.	Host plants dead.	Host plants dead.
24—8—33	Host plants affected.		

Copper sulphate of even 1% strength proved injurious to the host plants. In a subsequent trial still weaker solutions of copper sulphate were used. The spraying was done on 12—7—37. The results are recorded below.

Dates of observation	½ % solution	¼ % solution	Control
12—7—37	47 striga plants. 21 host plants. All healthy.	41 striga plants. 19 host plants. All healthy.	34 striga plants. 20 host plants. All healthy.
13—7—37	All the striga plants scorched and wilting. Host plants slightly affected.	All the younger ones among the striga scorched and wilting. Older ones badly affected. Hosts are healthy.	Both hosts and parasites healthy.
14—7—37	Striga all completely dead. 4 of the host plants wilting. The rest show signs of wilting.	All the striga plants fast wilting. Hosts healthy.	Both hosts and parasites healthy
15—7—37	No improvement in the hosts.	Striga all dead. Hosts healthy.	do.
17, 18 and 19—7—37	Hosts sickly.	Hosts healthy and normal.	do.

A quarter percent solution of copper sulphate kills the parasite striga without apparently affecting the host plant.

Economics of spraying with copper sulphate: The quantity of copper sulphate required for spraying an acre at the rate of 1000 c. c. of ¼% solution used for a sq. foot area works up to 240 lb. The cost of this will be at its cheapest Rs. 15 (pre-war-rate). The high cost, however, does not warrant its use considering the small income almost equal to it, proceeding normally from an acre of non-infected ***modan*** rice.

(c) *Common salt:* This in doses working out to 10 tons (22, 400 lb.), 20 tons and 60 tons per acre were applied to the potted rice plants infected with striga. In all the cases striga died instantaneously and thereafter the host plants too. In the case of 22,400 lb. there was no immediate effect on the host plant which, however, showed signs of wilting sometime later. It is clear therefore that any dose to achieve our objective should be less than ten tons. Even 1 or 2 tons will be too expensive for a ryot to use.

(iii) Dodging the parasite by adjusting the cultural practices : It has already been shown that early sowing does to a great extent provide a way out of the trouble due to this pest. The rule should be to sow rice with the help of pre-monsoon showers taking the earliest opportunity. As a rule, these showers are received in the month of April. Occasionally they might be received even earlier, 2 or 3 inches of rain, at times, are received within a week or two. Seeds when sown germinate in 3 or 4 days. The succeeding rains during this pre-monsoon period, even though they might be small and unsteady, help a good deal to force the young seedling up.

The regular monsoon commences generally by the third week of May. Even if the rice is sown by the first week of April or even earlier, the seedling once established are able to resist drought considerably till the break of the monsoon. At the Pattambi Agricultural Research station, in the year 1936, rice was sown with the help of the pre-monsoon showers on the 2nd of April. Regular monsoon commenced on the 28th of May. 1.34" of rain received since sowing the rice, was able to keep the crop going through an absolutely rainless period of 45 days immediately preceeding the outbreak of the monsoon on the 20th of May. The crop practically remained unaffected.

Early sowing, however, carries with it the risk of a long period of drought following. This necessarily causes some of the rice seedling to wilt and die. A fairly large percentage of the seedlings is destroyed by white ants, (a 30 days old crop showed 45%.) In another crop where plants were only 20 days old and therefore had not to contend so much a droughty weather as the earlier sown one, the plant population showed to be 70 percent of the seed sown. Ordinarily the seed rate adopted by the ryots under very favourable conditions for sowing ranges between 100 and

150 lb. per acre which is about 2 to 3 times that is ordinarily used for a broadcast crop under wet conditions. To provide against loss of plants due to drought when rice is sown early, the seed rate could with advantage be raised to 200 lb. per acre. The extra cost due to the excess seed may not cost the ryot more than a rupee (pre-war valuation) and will be more than justified by an almost normal crop ensured in an infected field by early sowing.

(iv) Cultivation of resistant varieties: Even rice varieties which grow in the swamp can grow under *modan* conditions though not so luxuriantely. Though no swamp varieties were actually tried, several of the dry rices that are grown in the tracts outside were collected and tried in a preliminary study to find out if there was any difference in the degree of pest incidence in them. The six varieties tried were *modan dirty glume, modan black glume, kattamodan straw glume, budama, chennellu,* and *chamodan* and their flowering durations varied from 85 to 105 days. Though sown at the same time no differences were noticed in the striga incidence. It may however be noted here that in a preliminary trial conducted to study the infectiousness of *Striga lutea* on crops other than rice, it was observed that *Striga lutea* did not attack P. T. 499, a strain of cumbu (*Pennisetum typhoideum*) evolved by the Madras Department of Agriculture although Sawyer (1922) has said that this millet was a host of the parasite.

(v) Biological control: This as a control measure employed by the entomologists to combat crops pests, has of recent years assumed great importance. If any insect could be found which will eat up striga and spare the rice, it will be a useful method of controlling striga. During 1935, the grubs of a certain species of beetle were found to be highly predatory on striga sparing no parts of its shoot system including the stem leaves and the pods. The adult which was found to be harmless was identified by the Government Entomologist, Coimbatore, to be a *Calurucine* beetle. This beetle should, therefore, provide an effective biological control if bred and released in large numbers during the season of rice cultivation in the infected areas. Though no experiments have however been done in this line, it would probably appear worthwhile investigating the problem.

Summary and conclusions.

1. The relevant literature available on *Striga* is briefly reviewed.

2. In the trial conducted to find out if *Striga lutea* attacked any other cereals besides its known hosts, it was found that it did not attack P. T. 499, a strain from Cumbu (*Pennisetum typhoideum*) which is known to be a host for this parasite.

3. Even when above ground, *Striga* is vitally dependent on the host plant.

4. *Striga lutea* does not thrive under aquatic conditions.

5. The incidence of *Striga* is controlled by season as well as the age and development of the host. The proper age and development of the rice plant appear to be essential to produce certain root exudations essential for stimulating the striga seed to germinate. The seasonal conditions at the on set of the South-West-Monsoon in June, perhaps brings about certain ideal physical conditions in the soil, which appears to be equally essential for the free germination of this seed. A rice crop being over 30 days of age before July is some what of an insurance against its succumbing to the parasite.

6. The superior performance of the earlier sown rice crop over the later sown one in the infected area is not so much due to any seasonal influence as to its dodging the *Striga* by passing the optimum conditions favouring an effective attack.

7. The injury done to rice by *Striga* is at its worst when the latter enters its reproductory phase and an early sown crop recovers from this injury much earlier than a late sown one.

8. The low incidence of *Striga* in the rice fields sown with its seed during the rainiest part of June may be due to the too wet condition of the soil.

9. Burning, uprooting and growing trap crops are some of the practical methods of control against *Striga*. Flooding is another method employed but this is not practicable in *modan* rice fields.

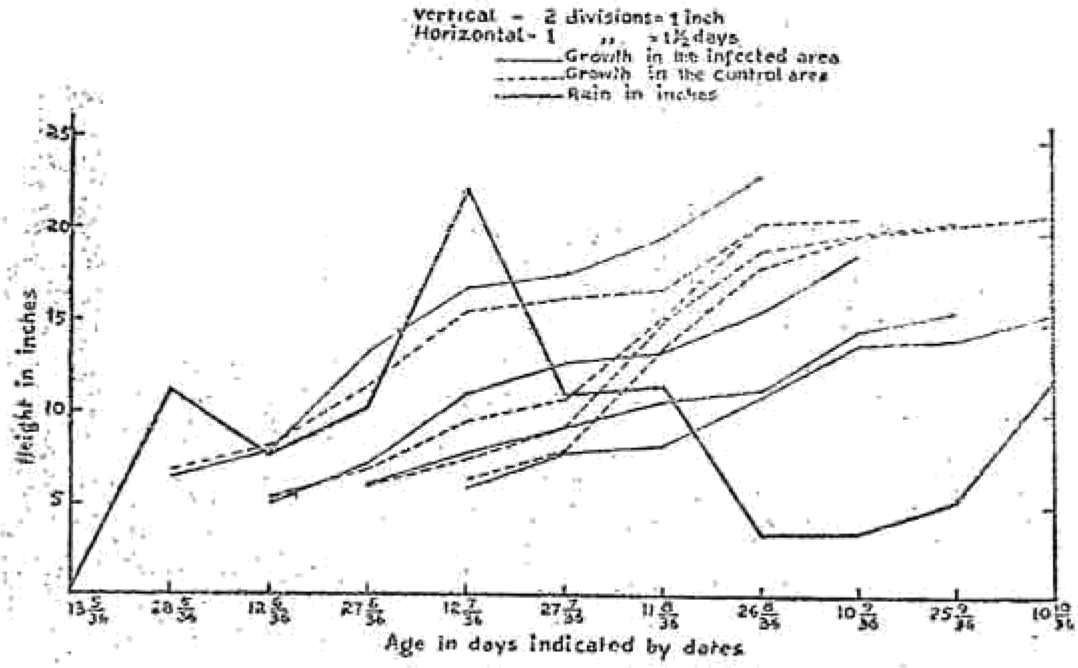
10. Weeding of the parasite affords only a partial relief to the rice crop.

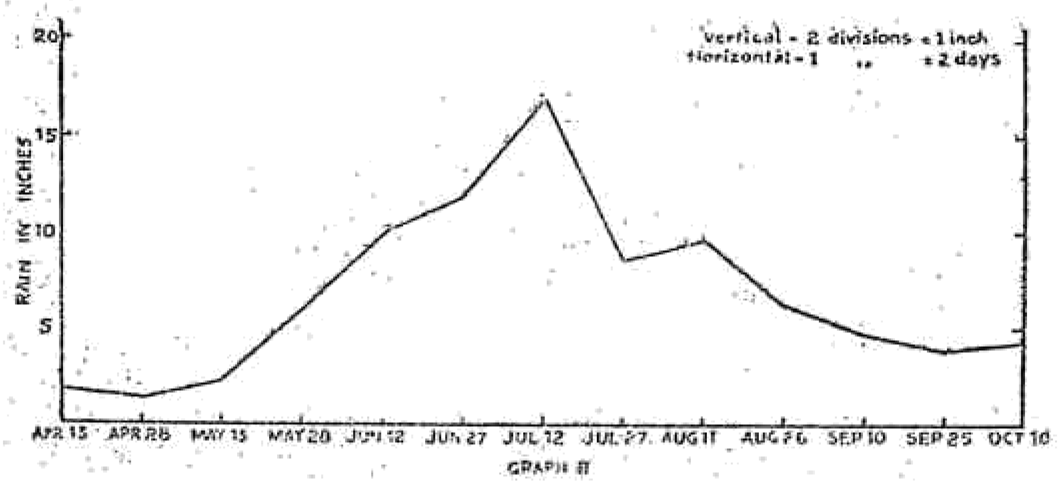
11. Lime in doses of 4000—8000 lb. per acre is found beneficial to the infected crop. A quarter per cent copper sulphate solution kills the parasite without appreciably affecting the host plant. Both these, however, are uneconomical to use on account of their high cost. Sodium chloride applied at 10 tons per acre killed the paresites immediately but not the host which however, succumbed after a week. Even one or two tons will be too expensive for a ryot to adopt.

12. Early sowing to a great extent provides a way out of the trouble due to this pest. Rice should be sown with the premonsoon showers taking the earliest opportunity. To provide against any loss of plants due to drought, the usual seed rate could with advantage be doubled.

13. None of the few *modan* rice varieties tried showed any varietal resistance against this parasite.

14. Grubs of a particular *Calurucine* beetle found to feed exclusively on *Striga* may be of potential value in the biological control of this parasite.


Vertical - 2 divisions = 1 inch
Horizontal - 1 ,, = 1½ days
Growth in the infected area
Growth in the control area
Rain in inches
Height in inches
Age in days indicated by dates


Vertical - 2 divisions = 1 inch
Horizontal - 1 ,, = 2 days
RAIN IN INCHES
APR 15
APR 28
MAY 15
MAY 28
JUN 12
JUN 27
JUL 12
JUL 27
AUG 11
AUG 26
SEP 10
SEP 25
OCT 10

GRAPH II

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Description of Graphs

Graph 1: Showing the growth of rice measured for the different sowings at different dates commencing from 15 days after sowing and ending some time before harvest and also showing the distribution of rain as recorded during these periods.

Graph 2: Showing 10 years average rain distribution for the period of *modan* rice cultivation at the Agricultural Research Station, Pattambi.