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EXPOSURE OF APPLICATORS DURING APPLICATION OF ALDRIN WITH KNAPSACK SPRAYER

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SUMMARY

Dermal exposure of pesticide applicators was assessed using aldrin as a model pesticide. Aldrin was applied with a Knapsack sprayer fitted with a brass solid cone nozzle. Four litres of aldrin in water (100 ml Aldrex 25 in 4.5 litres) was applied to 100 m plots of mixed weed crop maintained at 40 cm, 80 cm and 160 cm.

Exposure to aldrin spray drift was estimated by the quantitative assessment of aldrin in contaminated cloth patches located at various parts of the body of applicators. Amount of aldrin was determined by gas chromatography using an electron capture detector.

Dermal exposure of applicators increased from 11.29ug to 366.10 ug of aldrin with increase in spray height from 40 cm to 160 cm. Highest exposure level (202.6 ug) was recorded on left hand and arm that was directing the spray nozzle at 80cm crop height i.e. at 50% of applicators height.

INTRODUCTION

Aldrin is a non systemic and a persistent pesticide which has contact and stomach activity towards many insects (Brooks, 1974). Aldrin is mainly used against cut worms, wire worms, white grubs root worms and termites. It is also known to act as a fumigant in hot dry weather.

The LD 50 rat of Aldrin is 38 - 60 mg/kg body weight. The chronic and dermal toxicities to mammals appear to be relatively high. It is known that they are neurotoxicants and have effects similar to those of DDT and BHC. Applicators and other farm workers who enter treated areas may be exposed to pesticide drift and residues. Pesticides may enter the body through the mouth, lungs and skin. Although many workers have identified degree of pesticide exposure in large scale spraying (Wolfe et al.,1967; Tordior and van Heemstra, 1980) not much work has been done in the area of human exposure to pesticide under Sri Lanka conditions. Bandara (1987) reported the potential hazard to applicators using knapsack and hand compression sprayer due to spray drift during application based on the total number of spray droplets that contacted skin.

The objective of this study was to estimate the actual exposure by applicators during spraying with most commonly used knapsack sprayer.

MATERIALS AND METHODS

A lever operated knapsack sprayer (Baur's) of maximum capacity 18 litres was used. Brass soiled cone nozzle on a long lance was fitted to the sprayer. Mean delivery rate was adjusted to 660 ml/min. Same sprayer was used by all applicators.

Field Application

Commercial product of aldrin (HHDN), Aldrex 25% EC marketed by Unichem Limited was used as the test insecticide. Aldrex 25% EC contain 25% aldrin. Aldrex was applied at the manufacturers recommended rate of 60 ml of Aldrex in 4.5 l per 100 m . Each applicator on a given day applied the spray under the conditions tested. Spraying was done in plot with heavy mixed **weed** growth previously maintained at a mean height of 40 cm ,80 cm and 160 cm and they were approximately 25, 50 and 100% of the applicators mean height respectively. Each treatment was replicated three times.

Assessment of Exposure

Applicators were provided with a mask, cotton coverall, a pair of rubber gloves , a pair of rubber boots and a cotton cap. Cotton gloves were worn over the rubber gloves.

Insecticide deposits on each person were sampled with 10 sq.cm cotton cloth pads attached with plastic tapes to selected location on the white cotton coverall or directly layed on the bodies of the applicators. Locations as described by Kurtz and Bode, (1984) is shown in table 1. Pesticide deposits on hands were determined as reported by Bandara et al.(1984) using the whole glove as a sampling area.

Cotton pads, gloves and caps were prewashed by boiling in a detergent solution followed by boiling in distilled water for two hours and later autoclaving for one hour at 120 C at 15 psi.

Extraction of Aldrin

After each application individual cotton pads were removed with freshly clean forceps and placed in clean polyethylene bags and stored in the deep freezer until extractions were done. Each cloth pad was separately analysed for aldrin deposits. Cloth pads were cut into small pieces with a clean pair of scissors and the pieces were placed in a 500 ml Erlenmeyer flask, previously washed with sodium chloride solution and distilled water. Aldrin on cloth pieces were extracted into analytical grade acetone by shaking overnight in a orbital shaker. Mixture was then filtered through Whatman No 1 filter paper. Filtrate was evaporated to dryness in a flash evaporator.

Residue was redissolved in 5 ml of hexane and dried with 50 mg of anhydrous sodium sulphate by agitating hexane extract in a test tube on a test tube shaker and allowed to settle for five minutes before passing through a Whatman No 1. filter paper.

Column Clean Up

Hexane extract was purified using florisil and activated charcoal column (Zweig and Sharma, 1972.). Glass column (8mm id) was packed with 0.5 g of activated charcoal followed by 1g of florisil (100 - 200 mesh) and 0.5 g of anhydrous sodium sulphate. Column was washed with 5 ml of hexane before placing the extract in the column. Fifteen ml of 6% diethyl ether in petroleum was passed through the column and a uniform flow of eluting solvent was maintained during the process of cleaning the extract.

Standard Aldrin

Aldrin (HHDN) 1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-endo-exo-5,8-dimethanonaphthalene with 99% purity supplied by Polyscience Corporation, 7800 Merrimac avenue, Niles, Illinois 60648, USA was used as a standard test chemical in gas chromatographic analysis.

Gas Chromatography

Perkin Elmer Sgima 3B gas Chromatograph equipped with 63 Ni Electron Capture Detector was used. Separation was done with a glass column containing 1.5% OV - 17 + 1.97% OV 210 (80-100 mesh) of length 6 feet and diameter (o.d.) 1/4". Oven temperature at 200 C, detector at 275 C and Injector at 240 C were maintained throughout the process of analysis. Nitrogen was used as a carrier gas at a flow rate of 30 ml/min. Two microlitre samples were injected alternating with standard aldrin as a reference sample at every three injections of test sample.

RESULTS AND DISCUSSION

Exposure to the applicator depends on factors such as (a) time spend on application of pesticide (b) concentration of the formulation and the rate of application (c) application procedure and other environmental factors that affect the drift. (d) and personnel tidiness.

In this study time spent varied from 10 to 16 minutes from applicator to applicator and also between spraying at different plant height. This was mainly due to the fact that applicators were requested to apply a constant volume of 4.5 l of formulation per 100 sq.m area. All three applicators were right handed and therefore mean values for exposure were estimated (Table 2). Estimated area available for penetration and dermal exposure at various locations of the body are given in Table 1.

Table 1. Representative Body Area and Pad Locations.

Body part	Area sq.cm[a]	Pad location[b]	Pad area sq.cm
Face,neck	740		
Shoulder and upper arm	1250		
Chest	1850	chest	20
Fore arm	625	both fore arms	40
Hand	820	both hands	800-920

a - From Kurtz and Bode, 1984

b - used in this study.

Table 2 shows the actual amount of ai of aldrin reaching the applicator as a function of spray (plant) height. The amount of formulation reaching the head and the chest increases with increase in spray height. However the percentage exposure of head and chest remains low at lower plant heights 40 and 60 cm. These results fit the model proposed by Bandara (1987) where the percentage exposure was computed based on mean number of droplets per square centimeter caught by paper pads placed on applicators body.

Table 2 Amount of Aldrin Active Ingredient Extracted from Cotton Cloth Pads and Cotton Gloves of Applicators.

Location	Plant Height		
	40 cm x	60 cm	160 cm
	mean ug	mean ug	mean ug
Head	1.2 a	3.7 b	69.8 c
Hand - right	4.5 a	26.8 b	59.3 c
Hand - left	3.2 a	116.3 c	18.0 b
Fore arm - right	0.83a	12.0 b	109.5 c
Fore arm - left	0.66a	86.3 c	21.0 b
Chest	0.83a	18.8 b	88.5 c

x = Mean of three applicators

Values followed by the same letter in each row are not significantly different at p=0.05.

The total amount of aldrin ai. received by the applicator in this study is summarized in Table 3. The total contamination increased with plant height where the spray was directed at. The amount of aldrin sprayed at all three plant heights were kept constant at 15 g ai. however with increase in plant height the exposure to drift appears to increase significantly.

The lever of the spraying machine was operated by the applicators right hand and the nozzle and the lance by the left hand by all three applicators. This has significantly increased the aldrin deposits on the left hand at 80 cm plant height due to direct settlement of spray drift on the fore arm and the hand that directed the nozzle. This situation was reversed at higher spray height probably due to more of the drift settling on the right hand and the right fore arm that is operating the handle at much lower level (handle fixed to right hand bottom of the tank). This is clearly evident from the deposit figures at 160 cm. (Table 3).

Table 3. Total amount of aldrin recovered from cotton pads located on the applicator.

Plant height (Spray height) cm	Total amount of aldrin ai ug	Mean number[a] of spray droplets/sq.cm	Hand and Arm[b] Left ug	Right ug
40	11.29	97.84	3.93	5.33
80	263.95	383.90	202.6	38.8
160	366.10	287.90	39.0	168.8

a - Median droplet diameter 200-400 um, based on number deposited on 10 x 7 cm paper pads placed at a height of 40 cm from the ground.

b - Left arm & hand - carried lance and nozzle
Right arm & hand - operated lever of the tank

Levy et al., 1980, showed that exposure is greatest for those applying chemicals with knapsack sprayers as compared to ground machine. The level of exposure could be minimize through choice of proper protective clothing, proper formulations of chemicals and by correct use of equipment (Gunther et al., 1980)

In this study completed subsequent to authors previous report (Bandara, 1987) on human exposure , studies on contamination of foot, leg and scrotal area were not conducted as the percentage exposure was much lower also can be easily avoided by commonly worn clothings by most applicators.

It is proposed that the hazardous exposure of head, hand , arm and the chest could be reduced by wearing non absorbent type gloves, caps. Although non penetrating coveralls are desirable under Sri Lanka conditions it may be convenient to wear a thicker cotton coverall or a long sleeves shirt to cover the chest and the fore arms.

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EFFECT OF LEUCAENA AND GLIRICIDIA MULCHES ON THE GROWTH AND YIELD OF CHILLIES *(CAPSICUM ANNUM (L).)*

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INTRODUCTION

Agroforestry systems are becoming more popular among farmers in the tropics (Weerakoon and Seneviratne, 1984;Atta-Krah and Sumberg, 1987; Kang and Mulongoy, 1987; Wiersum and Dirdjosoemarto, 1987), although their benefits are not always proven (Kass and Araya, 1987). Chillies (*Capsicum annuum (L)*) are the most common subsidiary cash crop among farmers in Sri Lanka. An average of 13.878 ha/year is planted and a production of 981 kg/ha dry chillies is obtained (Anon., 1988).

Reduced growth and yield of chillies in alley cropping with *Leucaena leucocephala* (Lam.) de Wit were reported (Weerakoon, pers. comm.). The susceptibility of *Leucaena* to the psyllid *Heteropsylla cubana* might provoke its replacement by *Gliricidia* in avenue cropping systems (Wiersum and Dirdjosoemarto, 1987).

In this experiment the effect of two types of mulches on the growth and yield of chillies combined with chemical fertilizers was investigated.

MATERIALS AND METHODS

The experiment was set up in a tropical green house in Belgium with the following treatments in a 2x2x3 factorial design. No fertilizer and fertilized with 168 mg N/plant, 93 mg P, 332 mg K and 43 mg Mg was combined with dried litter of *Leucaena* and *Gliricidia* applied as mulch at three levels : no mulch, 6 t/ha or 12 g/pot and 12 t/ha or 24 g/pot.

Each pot was filled with 2 kg loam soil autoclaved at 121 ^{o}C, 15 lbs., two hours. Seventy five g soil, from a field in Sri Lanka with a history of *L. leucocephala* and *G. sempium* avenue cropping, was added to inoculate the soil. Prior to the start of the experiment, the pots were kept for one month to allow the bacterial culture to colonize the soil. The chillie cultivar MI 1 was disinfected with 8% NaCl for 5-10 min. and pregerminated on water-agar plates. Three day old seedlings were planted at three/pot and thinned unto one plant/pot one WAP. The dried *Leucaena* and *Gliricidia* litter was applied on top of the soil after establishment of the seedlings. Fertilization was done fortnightly on 5 occasions, starting before planting and ending at flowering time. Watering was done in the plate underneath the pot to avoid leaching of toxic products.

The experiment started on 04.12.1986 and the last harvest was taken 5.5 MAP. Pod picking started 4 MAP and was continued over four times. The dry weight and number of pods/plant were recorded. The plant height was measured 50 DAP. The shoot fresh and dry weight was determined at the end of the experiment.

RESULTS AND DISCUSSION

The total pod dry weight/plant increased significantly with fertilization (Table 1). The type of mulch had no effect but increasing the dose of mulch increased the pod production though not significantly.

The yield increases were due to a significant increase in number of pods after fertilizer application. Both doses of the mulch significantly increased the number of pods while the type of mulch had no effect. The number of pods/plant did not change significantly after doubling the mulch dose.

Table 1 : Growth and Yield Parameters of Chillies.

Treatment	Dry pod wt. /plant (g)	No. of pods /plant	Dry weight/pod (g)	Veget.dry wt. g/plant
Without Fert.	4.098[a]	7.33[a]	545.54	12.858[a]
Without Fert	5.211[b]	9.56[b]	547.12	16.067[b]
Gliricidia	4.654	8.958	541.42	14.246
Leucaena	4.655	8.333	551.25	14.679
No mulch	3.925	6.75[a]	607.69	12.094[a]
6 t/ha	4.589	9.19[b]	505.44	15.363[b]
12 t/ha	5.449	10.00[b]	525.87	15.925[b]

Figures with the same letter in a same column and group are not significantly different at P = 0.05.

The average weight/pod was not statistically different. Application of mulch tended to decrease the weight/pod.

The total vegetative dry weight increased significantly, but the rate applied had no effect. The interaction was not significant, though Wiersum and Dirdjosoemarto (1987) found that a combination of *Gliricidia* litter and fertilizer increased the dry matter production when compared to litter alone.

The plant height at 50 DAP did not differ significantly among the treatments.

The data suggests that a positive effect of both mulches was observed on the growth and production of chillies. Guevarra (1976), Chagas (1981) and Atta-Krah and Sumberg (1987) obtained similar results. Mulch of *Leucaena* and *Gliricidia* at 6 and 12 t/ha was as effective as inorganic fertilizer as the leaves decomposed rapidly (Kang and Mulongoy, 1987). Mulching was most effective for pod production. The yield increase was mainly due to an increased number of pods although the average pod weight decreased. The combination of mulch and fertilizer was not consistent for both parameters. *Gliricidia* increased also the vegetative production, though no statistical differences between the mulch types were observed.

The negative effects observed (Weerakoon, pers. comm .) could be due to the presence of the avenue tree, effects such as root exudates and competition for water, nutrients and light between the trees and the crop (Obando, 1987).

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POLLINATION AND FRUIT SETTING STUDIES ON CARICA PAPAYA (L) - VARIETY CO-2

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SUMMARY

Studies on pollination and fruit setting was carried out in Carica papaya L., variety CO-2 at the Minor Export Crops Station, Matale in 1979. Pollination one day after anthesis scored the highest percentage (100%) fruit set followed by control (no pollination) (95.24%) and one day prior to anthesis (90.48%). Pollination with foreign pollens oil palm scored the lowest % of fruit set (47.62%). Pollination one day after anthesis scored lowest dropping of pollinated flowers and immature fruit. The highest mean length and diameter for the fruits and mean seed weight were scored by the same above treatment. Seed development was lacking in treatments, pollination with foreign pollen and the control. In these treatments, the fruits also were smaller in size.

INTRODUCTION

The method of natural pollination in papaw is not known with certainty. There is conflicting opinions on natural pollination. It is variously stated that papaw is wind pollinated as the pollen is light, and produced in large quantities (Perest, 1955), or insect pollinated by small insects like thrips, and moths (Purseglove, 1968; Hayes, 1960). After pollination, pollen germination is dependent upon the receptivity of the stigma, a condition assumed to be associated with the sectetion of the stigmatic fluid. **Pollination** tests show that flowers artificially pollinated 2 to 3 days before the petals normally unfold will set fruit, which seems to indicate that the pollen on the stigma remains capable of germination until receptivity occurs. In pear varieties receptivity is reported to vary from 3 to 4 days according to the variety (Gourley and Howlett, 1959). Artificial pollination, at the high receptive condition, has beneficial effect by increasing fruit set. Jacob (1973) reported that the fruit set was highest (70%) when the flowers were pollinated one day after anthesis (high receptive time). In papaw studies on this aspect are limited. Hence, this study was undertaken to investigate the increase in fruit setting and decrease the fruit drop by artificial pollination.

MATERIALS AND METHODS

The study was conducted at the Minor Export Crops Research Station (IM_3, AMSL) Matale in 1979. Out of 50 plants from half an acre plot, 25 female and 10 male plants were selected. Disease free, healthy and plants bearing fruits were selected. No bisexual plants were selected. With varying stages of flower development seven different methods of pollination were carried out. T_1-pollinations one day prior to anthesis, T_2 on the day of anthesis, T_3 one day after anthesis, T_4 two days after anthesis, T_5 three days after anthesis, T_6 with oil palm pollens and T_7 - control. For each treatment 21 flowers (3 sets of seven flowers each) were used. Thus a total of 147 (7x7x3) flowers were used in the experiment. Three sets of pollinations were made on 1st of May, June and July, 1979. Healthy female flower buds were selected. All the buds for various treatments except T_1, were covered with small (8x5 cm) thin cloth bags one day before anthesis. But in the first treatment flower buds were covered two days before anthesis.

Healthy male flowers at the correct stage of maturity were selected. Petals were removed, so as to expose stamens, enabling easy and direct transfer of pollen without additional instruments. The exposed stamen was carefully brushed over the stigma, in treatments T_1 to T_5. In T_1 buds were pressed opened and pollinated. For T_6, pollen was collected from male oil palm inflorescence and pollinated with female papaw. In all the treatments, immediately after the pollination flowers were rebagged.

The flowers were observed daily for fruit set. Three days after pollination, the bags were removed. Flowers were observed for colour change of stigma, fall of petal, drying and falling of stigma and ovary development. Flowers that stayed on the tree for three days after pollination were recorded as "fruit set". Young fruits that were fall after three days were considered as immature fruit fall. On the 14th day after pollination, the length and breadth of the fruits were measured by a "veniar calipers". One month after pollination, three fruits were randomly selected from each treatment of the 3rd set of pollinations and were used for the study of the following parameters, such as presence or absence of seeds and weight of 25 seeds. Treatment average were obtained by averaging the 3 samples.

RESULTS AND DISCUSSION

The effect of different pollination treatments on fruit set are presented in Table 1. Pollination treatments showed a highly significant influence on fruit set. Among the seven treatments, T_3 (pollination one day after anthesis) scored the highest percentage of fruit set (100%). Result obtained by Jacob (1978) in Cola nitida which scored highest percentage fruit set when the flowers were pollinated one day after anthesis. In Cola nitida the highest percentage (38%) with all the five follicles was also obtained for pollinations one day after anthesis. But the fruit set percentage, of T_3 was not significant with setting percentage of T_1 - control. T_1 (pollination one day prior to anthesis) and T_4 (pollination two days after anthesis). The lowest percentage fruit set (47.62%) was scored by T_6 (pollination with foreign pollen). This was not significant with that of T_2 (pollination on the day of anthesis) and T_5 (pollination three days after anthesis). It is interesting that the treatment T_2 scored only 66.67% of fruit set.

Table 1 : Number of Flowers Pollinated (P), Number of Fruit Set (3 days after pollination) (S) and Percentage (%) in Three Sets of Seven Treatments.

	1st set			2nd set			3rd set			
Treatment	P	S	%	P	S	%	P	S	%	Mean %
Pollination one day prior to anthesis (T_1)	7	6	85.71	7	6	85.71	7	7	100.00	90.47^{ab}
Pollination on the day of anthesis (T_1)	7	5	71.43	7	4	57.14	7	5	71.43	66.67^{cd}
Pollination one day after anthesis (T_3)	7	7	100.00	7	7	100.00	7	7	100.00	100.00^{a}
Pollination two days after anthesis (T_4)	7	6	85.71	7	5	71.43	7	6	85.71	80.95^{abc}
Pollination three days after anthesis (T_5)	7	6	85.71	7	5	71.43	7	5	71.43	76.19^{bcd}
Pollination with foreign pollens (T_6)	7	3	42.86	7	3	42.86	7	6	85.71	57.14^{d}
Control (no polli-nation (T_7)	7	7	100.00	7	6	85.71	7	7	100.00	95.24^{ab}

Figures followed by the same letters are not significantly different ($P < 0.05$)

From these results, we can say the receptivity of stigma remains more than one day (from one day prior to anthesis to two days after anthesis). In many crops the receptivity of stigma remains more than one day. Senanayake and Thiruketheswaran (1978) reported that winged bean was receptive from 24 hours before flower opening to 34 hours after flower opening. In clove Sritharan and Bawappa (1981) found that the stigma remains receptive for about two days after anthesis.

It could also be seen from this study that artificial pollination ensures a very high fruit percentage (100%). In another pollination study in papaw, artificial pollination gave more than 90% fruit set (Parthipan, 1984). Naik and Rao (1943) and Singh (1960) using two varieties of mango said hand pollination is conducive to more fruit than natural open pollination. In Cola nitida, under artificial pollination, the maximum fruit set was 70% (Jacob, 1973).

Fruit set showed a significant seasonal effect as the three group of pollination were made in different month. Month to month the ecological factors, including temperature, rain fall, wind and humidity and insects activity were different and these factors have influence on fruit set (Gourley and Howlett, 1959).

Immature fruit drop in various pollination treatments is presented in Table 2. Treatment showed a highly significant influence on immature fruit drop. Treatment T_3 scored the lowest percentage of immature fruit drop (4.76%) and this was significantly lowest from all the other pollination treatments. The highest percentage immature fruit drop (70%) was scored by control (T_7). The immature fruit with fertilized eggs normally fall in many fruit trees, such as apple, peach, plums and cocoa (Luckwell, 1953). In mango, Maurya and Singh, (1979) used different growth regulators (NAA, 2, 4-D and 2, 4, 5-7) to reduce the immature fruit drop. But in the present study in papaw, the immature fruit drop was reduced by pollination treatments. This kind of pollination treatments might be applied to other fruit trees to reduce the immature fruit drop. Immature fruit drop also showed significant seasonal effect because of the same reasons (ecological factors) mentioned above.

Table 2 : Fruit Set Three Days After Pollination (S), Number of Immature Fruit Dropped (D) and Percentage Immature Fruit Drop (%) in Three Sets of Seven Treatments.

Treatments	1st set			2nd set			3rd set			
	S	D	%	S	D	%	S	D	%	Mean %
Pollination one day prior to anthesis (T_1)	6	2	33.33	6	3	50.00	7	3	42.86	42.06^{a}
Pollination on the day of anthesis (T_2)	5	1	20.00	4	1	25.00	5	1	20.00	21.67^{b}
Pollination one day after anthesis (T_3)	7	0	00.00	7	0	00.00	7	1	14.29	4.76^{c}
Pollination two days after anthesis (T_4)	6	1	16.67	5	1	20.00	6	2	33.33	23.33^{b}
Pollination three days after anthesis (T_5)	6	2	33.33	5	1	20 00	5	1	20.00	24.44^{b}
Pollination with foreign pollens (T_6)	3	1	33.33	3	0	00.00	4	2	50.00	27.78^{ab}
No pollination control (T_7)	7	5	71.43	6	4	66.67	7	5	71.63	69.91^{d}

Figures followed by the same letters are not significantly different ($P < 0.05$)

Table 3 : Number of Flowers Pollinated (P), Total Dropped (Pollinated Flowers and Fruits) (T) and Percentage Total Drop (%) in Three Sets of Seven Treatments.

	1st set			2nd set			3rd set			Mean%
	P	T	%	P	T	%	P	T	%	
Treatments										
Pollination one day prior to anthesis (T_1)	7	3	42.86	7	4	57.14	7	3	42.86	47.62^b
Pollination on the day of anthesis (T_2)	7	3	42.86	7	4	57.14	7	7	42.86	47.62^b
Pollination one day after anthesis (T_3)	7	0	00.00	7	0	00.00	7	1	14.29	4.76^c
Pollination two days after anthesis (T_4)	7	2	28.57	7	3	42.86	7	3	42.86	38.10^b
Pollination three days after anthesis (T_5)	7	3	42.86	7	3	42.86	7	5	42.86	42.86^b
Pollination with foreign pollen (T_6)	7	5	71.43	7	4	57.14	7	5	71.43	66.67^a
No pollination-control (T_7)	7	5	71.43	7	5	71.43	7	5	71.43	71.43^a

Figures followed by the same letters are not significantly different ($P < 0.05$)

The number of flowers and young fruits abscised (total drop) in various pollination treatments presented in Table 3. Same trend was observed in total drop. Treatments showed a highly significant effect on total drop. Among the seven treatments, T_3 had the lowest percentage total drop (4.76%) followed by T_4 (38.10%). The highest percentage total dropping (71.43%) was evident in the control (T_7) where the flowers were not pollinated. In mango, the fruit set percentage was low because of a large number of female flowers that remain unpollinated (Singh, 1954). Total drop also showed significant seasonal effect because of the same reason (ecological factors) mentioned above.

The mean length and diameter of developing fruits and the mean weight of 25 seeds in the seven pollination treatments are shown in Table 4. The highest mean length and diameter for the fruits were scored by T_3 . But this was not significant from T_1, T_2 and T_4. The highest mean weight of 25 seeds was scored by T_3 and T_2. But these are not significant with T_4. In pollination treatments T_6 and T_7, the seeds were not developed. This partly explains the common occurence of seedless fruits (Parthenocarpic fruits) in papaw (Chema and Dani, 1929). They reported that the percentage of seedless fruits under normal condition was 7%. So in treatments T_6 and T_7 fertilization may not have taken place. Parthenocarpic fruits are common in many fruit trees like orange, pears, grapes and banana (Chandler, 1957 and Gourley and Howlett, 1959). These two treatments scored the lower values for fruit size.

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Table 4 : Mean Length and Diameter of Fruits and Mean Weight of 25 Seeds in Seven Treatments.

Treatment	Mean fruit length cm.	Mean fruit diameter cm.	Mean weight of 25 seeds (g)
Pollination one day prior to anthesis (T_1)	5.57^a	2.55^a	0.17^c
Pollination on the day of anthesis (T_2)	5.80^a	2.52^a	0.39^a
Pollination one day after anthesis (T_3)	5.90^a	2.86^a	0.39^a
Pollination two days after anthesis (T_4)	5.40^a	2.49^a	0.37^a
Pollination three days after anthesis (T_5)	3.50^b	1.50^b	0.29^b
Pollination with foreign pollens (T_6)	1.98^c	1.01^c	-
No pollination-control (T_7)	1.98^c	0.87^c	-

Figures followed by the same letters in each column are not significantly different ($P < 0.05$)

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EFFECT OF ALUMINIUM, IRON AND MANGANESE ON NITRIFICATION IN PEAT.

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SUMMARY

Nitrification in the presence of 0 to 3000 µg of each of Al, Fe and Mn as chlorides in peat (g^{-1}) has been studied. About up to 40 days the added elements could not produce any appreciable change in the processes of N mineralization and transformation. However, thereafter the salts suppressed nitrification and encouraged ammonification. The interalia transformation of N increased with concentration having the threshold value of 2000 µg^{-1} peat. The divergence of two trend (ammonification and nitrification) in the presence of metals attained the maximum at about 80 days. Addition of elements in freshly prepared peat was found to be more responsive than the aged one.

INTRODUCTION

A lot of research has been conducted on the role of trace elements in plant growth and the factors affecting their availability in soil, but their influence on biochemical behaviour of soil microorganisms has not received much attention. Information available suggests that addition of trace elements can alter the mode of nitrogen metabolism reactions in soil either additively or antagonistically. The critical concentration, of course, depends on the nature of element. (Lipman and Burgess, 1914; Lees and Meiklejohn, 1948; Premi and Cornfield, 1969). Research in this respect so far has been done mainly on cultivated soils.

Studies on the role of metals in soils are difficult to plan and put into practice. The choice of medium of correct soil environment conditions for this type of experiment present problems because of the inherently high content, but not easily available, of iron and aluminium in mineral soils at normal pH; and again, of their unavailability in organic soils due to the formation of organic complexes. However, in contrast to the mineral soils, the iron and aluminium content in organic soils is generally low and becomes available only at low pH. Hence, an acid peat was chosen as the suitable medium to study the impact of metals on N transformation.

Aluminium, iron and manganese are usually dominant in acid soils; and thus, to stimulate the required soil environment metal salts of these elements were selected for application in the acid peat. The objective was to follow their ability to alter nitrogen changes through modification of the ammonifier and nitrifier activities in peat.

MATERIALS AND METHODS

Commercially available Fisons peat (I) was collected, air-dried and passed through 2 mm sieve. The physical and chemical characteristics of the peat are pH 4.3, organic matter 41.4, total N 1.6 and CEC 902 me/kg.

The experiment was carried out in two sets following a randomized block design with two replications. The first set was conducted using only one treatment-$AlCl_3$, and the second set was arranged after 4 months of the first with Fe and Mn chlorides treatments for 100 days. 50g air-dry peat was weighed out into a series of clean-dry 500 conical flasks. Five doses (0,500,1000, 2000 and 3000 $\mu g\ g^{-1}$) of aqueous solutions of each treatment applied separately. The shift of pH caused with added salts was corrected with lime as estimated from pH lime curve. The peat was incubated at 50% WHC at 25^{o}C with clingfilm covering. A constant moisture content was maintained all through by making up the loss of moisture, and aerated every day by removing the clingfilm cover for 5 mins. Samples were collected from each flask, in triplicate, at an interval of 10 days. The collected samples were extracted with 1 M KCl for the determination of mineral-N, Al, Fe and Mn.

pH was determined by a combined glass/calomel electrode using a model 7020 pH meter (peat: water ratio being 1:2.5), in the beginning and at the end. Estimation of organic carbon by wet oxidation (Tinsley, 1970), total N by Kjeldahl digestion, CEC by 1 M NH_4OAc (pH 7.0), Fe and Mn by atomic absorption spectrophotometer (Shandon Southern model A 3400), Al (Edwards and Cresser, 1983) and NH_4-N and (NO_2+NO_3)-N colorimetrically using a Technician Auto-Analyzer were carried out.

RESULTS AND DISCUSSION

Transformation of peat bound N in the present investigation was found to be influenced by added metals (Figs. 1A-3A). Release of NH_4-N in Al-treated samples (first set) increased up to 30 days (Fig. 1A), maintained almost a steady state up to 40 days, then deviated from the control with very rapid increase and attained the maximum value on 70 days followed by a sharp decline; and then again, assumed a steady state after 90 days irrespective of the level of treatments.

In the presence of Fe and Mn (second set, Figs. 2A and 3A), the release of NH_4-N reached the maximum in 20 days time followed by a sharp decline up to 40 days, thence the release increased up to 60 days and became almost steady up to 90 days (except 500 $\mu g\ g^{-1}$) followed by a shoot up release.

Transformation trends of NH_4-N are almost similar to that of the controls up to 40 days whatever may be the types and levels of treatments. The treated ones then deviated and showed upward trend whereas the control went down up to 80 days. Both the control and the treated samples resembled each other in the trend after 90 days. Lowering of C:N ratio with prolonged incubation may have accentuated the mineralization of organic nitrogen.

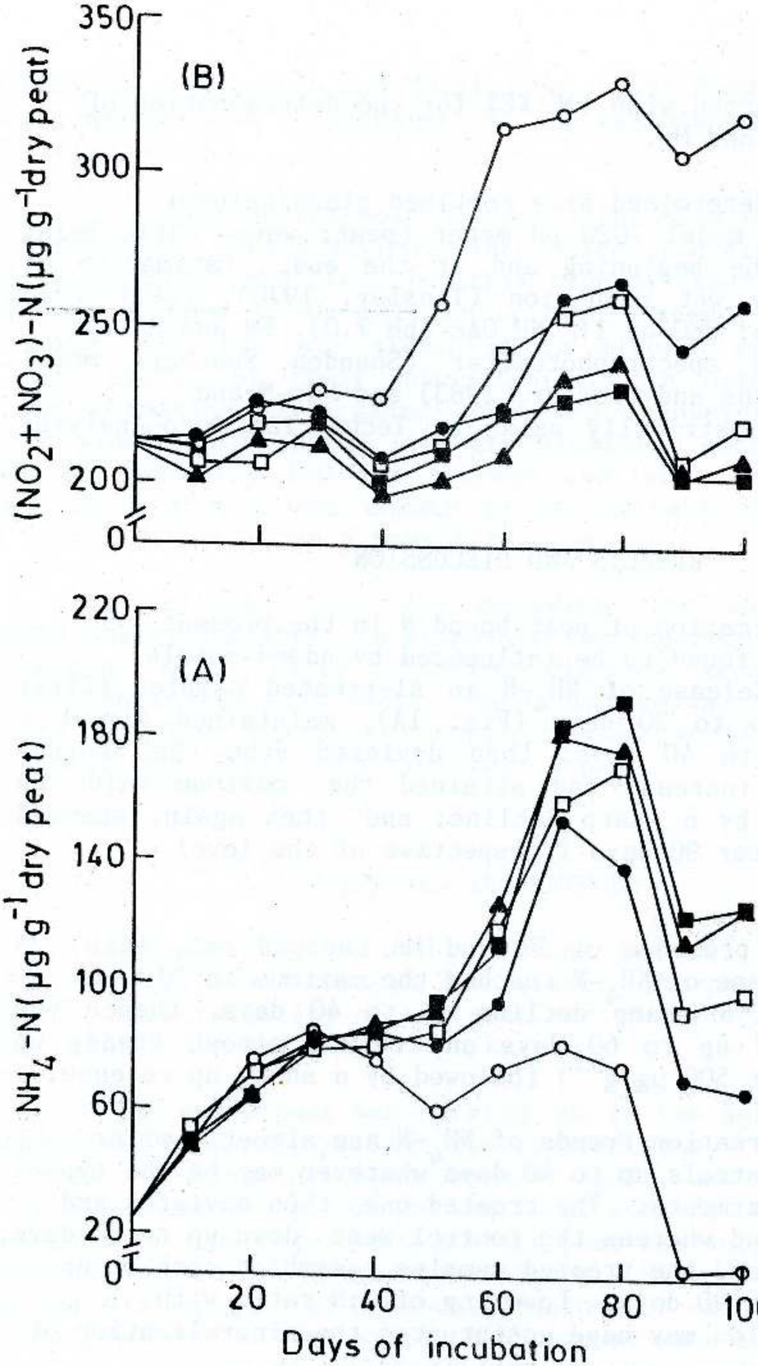

Fig. 1 Changes in NH_4-N (A) and (NO_2+NO_3)-N (B) as influenced by $AlCl_3$ during aerobic incubation of Fisons peat (I). Legends : O——O 0/ug g^{-1}, ●——● 500 /ug g^{-1}, □——□ 1000/ug g^{-1}, ■——■ 2000 /ug g-1, ▲---▲ 3000 /ug g^{-1}

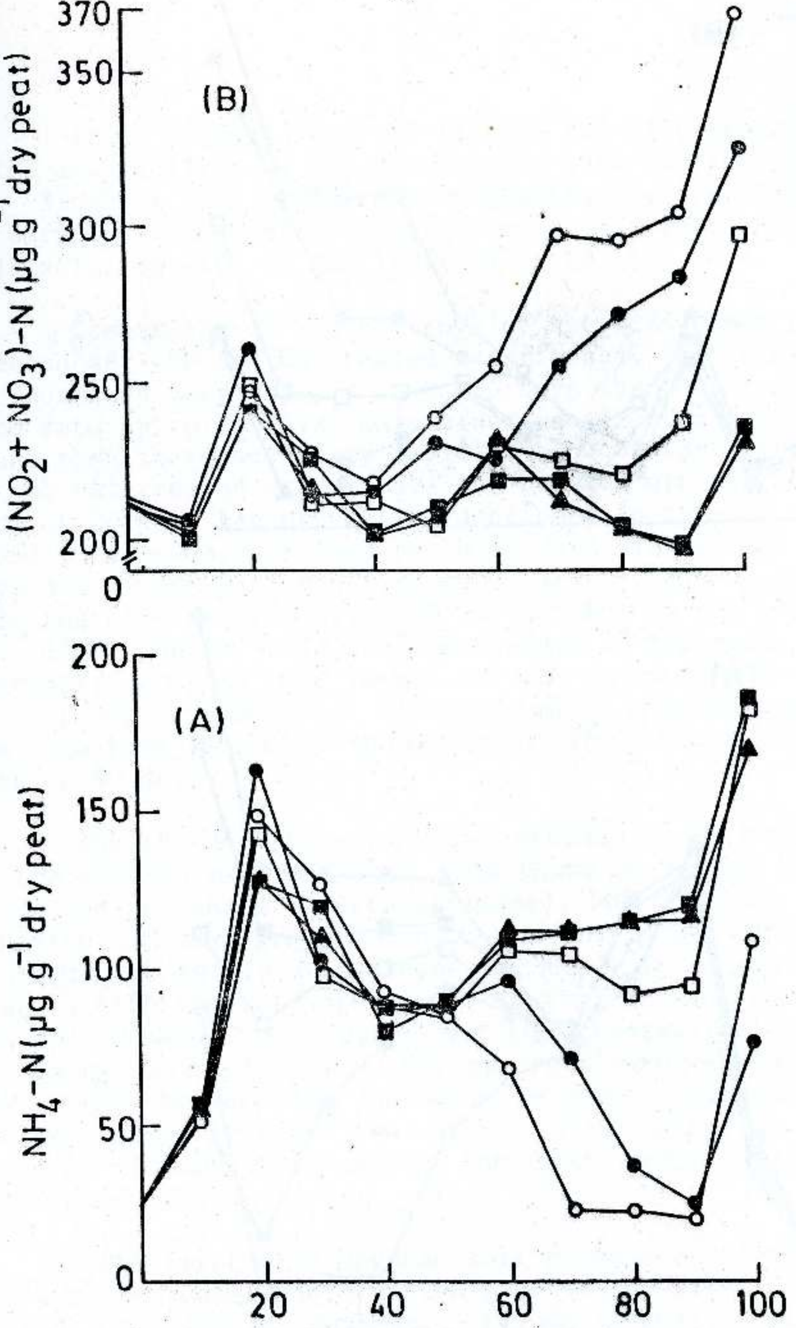

Fig. 2 Changes in NH_4-N (A) and (NO_2+NO_3)-N (B) as influenced by $FeCl_3$ during aerobic incubation of Fisons peat (I). Legends : see Fig. 1.

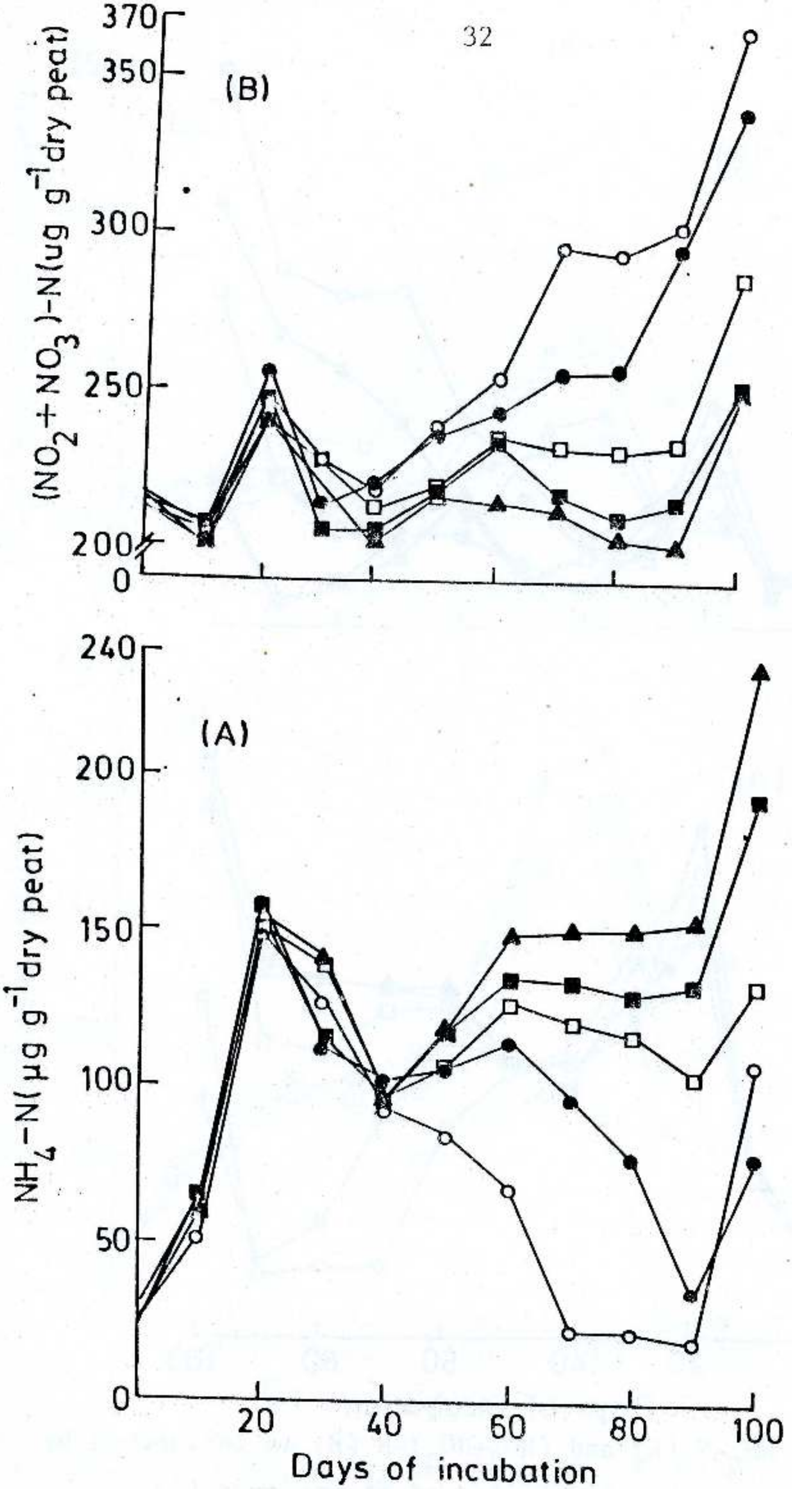

Fig. 3 Changes in NH_4-N (A) and (NO_2+NO_3)-N (B) as influenced by $MnCl_2$ during aerobic incubation of Fisons peat (I). Legends : see Fig. 1.

It is evident from the figures (1A-3A)(first set) that the availability of NH_4-N increased with the increase of the doses. Singh et al. (1969) also suggested that release of NH_4-N was a direct function of concentration of chlorides of Al and Fe in soil solution with in the limit 0 to 1M.

Comparison of the controls of the sets shows that in the second set (Fe and Mn treated experiment), the release of NH_4-N increased very rapidly up to 20 days then declined almost in same rate up to 70 days, maintained equilibrium for about 20 days and then increased very rapidly. In contrast, in the first set (Al treated experiment) the control did not attain maximum at 20 days but otherwise continued to rise up to 30 days and remained almost same up to 80 days with slight fall on 50 days and a somewhat boosting on 70 days. Careful analysis reveals that the release of NH_4-N in the peat is not element bound. If Fe and Mn would have been added to the peat concurrently with Al the nature of the graph could have the same sort of appearance. Nevertheless, treatment with the metals resulted positive effect over the control though at a lapse of 40 days.

Though the shapes of the graphs of Al treated vis-a-vis the control are different from those of Fe and Mn treated ones (Mn and Fe ones are virtually same), but critical examination of the graphs reveals on an first approximation that impact of metals on release of NH_4-N in comparison with control in both the sets are almost equivalent i.e. the difference between the control and the treated one are almost same irrespective of time. The apparent contradictory change in the graphs between the two sets is easily comparable with the time lapse between two sets. Presumably a reconable biochemical change occurred in the peat prior to the start of the second set.

Experiment with organic soil present problems peculiar to its one time autotransformation even in the air-dried condition followed by wetting. If we compare Fig. 1A with Figs. 2A and 3A, the prominent hump is conspicuous in about 20 days time (Figs. 2A and 3A) and disappeared from the peat which was cured at room temperature for 120 days (Fig. 1A).

On comparison of both the sets of experiments at 80 day run, amount of NH_4-N released was much higher in Al treated one than that of Fe and Mn treated ones. Apparent immediate NH_4-N economy attainable if peat is not air-cured (Figs. 1A-3A).

The trend of release of (NO_2+NO_3)-N (Figs. 1B-3B) up to 40 days were almost prototype to that of NH_4-N (Figs. 1A-3A) with slight exception at 10 days in the second set where the amount of (NO_2+NO_3)-N declined a little bit. However, the amount released was higher than that of NH_4-N in all cases. After 40 days, (NO_2+NO_3)-N graph proceeded in the reverse direction with respect to control as well as NH_4-N. The divalgent trend of (NO_2+NO_3)-N was probably due to the fact of inhibiting impact of metals on nitrifying bacteria or otherwise. The receprocity in (NO_2+NO_3)-N release was very much indicative of the fact that these metals suppressed nitrification resulting in an accumulation of NH_4-N by stimulating ammonifiers. The decreased yield of (NO_2+NO_3)-N was not obviously due to denitrification, because the total $N(NH_4\text{-}N + NO_2\text{-}N + NO_3\text{-}N)$ at all stages of incubation were same with experimental limit with respect to control. In both the processes of N transformation all the metals were almost equally effective. Contrary to this result Greaves (1922) assessed that Fe was more toxic than Mn and Al was more detrimental in comparison to Fe (Singh _et al_.,1969) to activity of nitrifiers. Singh _et al_. (1969) also reported that Al and Fe (0 to 1M) in soil solution had very little effect on nitrification. It is peculiar to note that the control follows the trend of metal treated samples in NH_4-N and Vice-versa. Nitrifiers seems to be more active than ammonifiers up to 40 days whether treated or not.

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STUDY OF THE TIME FACTOR INVOLVED TO EQUILIBRIATE MOISTURE CONTENT IN PADDY

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Moisture content of the paddy is an index to determine the stage of harvesting, quality for safe storage and feasibility of milling with maximum head rice recovery. The moisture content of newly harvested paddy ranges from 18-22% and is too wet for milling or storage. Paddy should be shade dried to obtain maximum head rice recovery during milling. During shade drying water in the rice grain reach a characteristic balance or equilibrium with water vapour in the air. Hall (1970) pointed out that the grains take up or lose water during storage depending on the climatic conditions. According to Oxley (1948) many workers investigated the relation between grain water and atmospheric humidity, but reported widely different results. Since relative humidity in the microclimate of storage systems depend on the initial moisture content of the grain in addition to the outside changes; it is important to adjust the initial moisture content to the equilibrium position for storage purposes to minimize the moisture loses and their movement which create disturbances like hot - spots. This study was undertaken to determine the time taken by paddy at different initial moisture levels to reach the equilibrium moisture content.

One kg samples of rough rice from rice varieties, BG 276 -5, BG 34 -6, BG 94 -1 and BG 400-1 were selected. The initial moisture content of the samples which was around 13% was increased by adding water to the desired levels of 14%, 15%, 16% and 17%. Moisture content was determined using Satake Moisture meter. The amount of water to be added was calculated from the following **equation** ,

$$W_x = \frac{G_o (Mo_2\% - Mo_1\%)}{100 - Mo_2}$$

where , W_x = water to be added, G_o = initial wt. of grain, Mo_1 = initial moisture content, Mo_2 = required moisture levels.

Calculated quantities of water were added to rough rice in glass bottles to obtain the different initial moisture levels. The bottles were shaken thoroughly. These samples were stored in paper bags under laboratory room conditions. Moisture contents were determined on the following day to check whether the samples had attained the expected moisture levels. Moisture contents were recorded at three day intervals. The relation between time and moisture content was observed from plotted diagrams and curves were fitted to the data.

These moisture contents were observed to be decreasing with time (Table 1). Pattern analysis from plotted diagrams and statistical analysis showed that the decrease of moisture content with time followed a specific type of polynomial pattern, $Y = a + bX + cX2$, with high correlation coefficients. These relationships were obtained seperately for different varieties at different initial moisture contents.

According to the computed relations the time taken to attain equilibrium moisture content was found to be around 21 days irrespective of initial moisture contents. The computed equation for the respective curves with their correlations are given in Table 2.

According to Oxley (1948) the final equilibrium state cannot be demonstrated in practice. Hence the minimum moisture content was computed using equations derived for different varieties at different initial moisture contents. They were found to be in the range of 12.07 - 12.78 (Table 2).

This indicates that the moisture content of paddy should be kept within this range for storage purposes in order to minimize moisture loses. Moreover, newly harvested paddy should be shade dried at least 21 days for it to attain an equilibrium point under the studied conditions (at 25 - 28^{o}C room temperature and 56 - 68% relative humidity). However the equilibrium state

Table 1. Observed Seed Moisture Contents of Rice Varieties.

Variety	Initial Moisture%	Dates Observed 0	3	6	9	12	15	18	21	24
BG 94-1	14	14.4	13.7	13.4	13.0	12.7	13.0	12.4	12.9	12.4
	15	15.3	14.4	13.9	13.1	12.8	13.0	12.6	12.9	12.3
	16	16.2	14.4	13.8	13.9	12.8	13.1	12.5	13.1	12.4
	17	17.0	16.0	14.5	14.1	13.3	13.2	12.7	13.0	12.5
BG 34-6	14	14.3	14.2	13.8	13.3	12.7	12.9	12.5	12.8	12.3
	15	15.2	14.7	13.9	14.0	12.9	13.1	12.8	13.0	12.4
	16	16.1	14.8	13.9	13.9	13.0	13.1	12.7	12.9	12.5
	17	16.8	15.8	14.5	14.2	13.1	13.2	12.8	13.0	12.8
BG 400-1	14	14.0	13.5	13.2	13.1	12.4	12.7	12.2	12.5	12.1
	15	14.8	13.9	13.3	13.2	12.6	12.7	12.4	12.6	12.2
	16	15.8	14.0	14.0	13.0	12.5	12.7	12.3	12.6	12.2
	17	16.8	15.5	14.1	13.6	12.9	12.7	12.6	12.8	12.3
BG 276-5	14	14.2	14.0	13.9	13.9	12.9	13.0	12.7	13.0	12.6
	15	15.2	14.3	14.1	13.8	13.5	13.3	13.0	13.0	12.9
	16	16.0	15.4	14.2	14.1	13.5	13.3	12.9	13.0	12.7
	17	17.0	15.5	14.6	14.2	13.2	13.2	13.0	13.1	12.7

Table 2. Regression Estimates for Different Curves.

Variety	Initial Mo%	Model $Y = a + b X + c X^2$ a	b	c	r^2	Estimated Mo%
BG 94-1	14	14.27	-0.167	0.004	0.90	12.52
	15	15.13	-0.242	0.006	0.94	12.49
	16	15.69	-0.293	0.007	0.89	12.51
	17	16.87	-0.379	0.008	0.97	12.50
BG 34-6	14	14.42	-0.138	0.002	0.93	12.14
	15	15.19	-0.205	0.004	0.93	12.57
	16	15.80	-0.293	0.007	0.95	12.55
	17	16.72	-0.373	0.009	0.98	12.68
BG 400-1	14	13.95	-0.137	0.004	0.93	12.66
	15	14.57	-0.200	0.004	0.95	12.07
	16	15.39	-0.308	0.007	0.92	12.18
	17	16.55	-0.400	0.009	0.97	12.29
BG 276-5	14	14.36	-0.122	0.003	0.85	12.74
	15	14.95	-0.142	0.002	0.95	12.28
	16	15.98	-0.270	0.006	0.98	12.78
	17	16.72	-0.369	0.009	0.97	12.71

may vary with temperature and other environmental conditions prevailing in different ecological zones.

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SUPPLY RESPONSE FOR EGG PRODUCTION IN THE RURAL FARMS, KANDY DISTRICT

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SUMMARY

The main objective of this study was to determine the supply response of egg production among the farmers in Kundasale, Patha Hewaheta, Udu Dumbara, Gangaihala, and Minipe in Kandy district. A random sample of 125 poultry farmers was subjected to a field study. The supply response analysis consisted of equations for chicks, growers, and egg production with average layer productivity as an identity. The equations were estimated by Zellners Seemingly Unrelated Regression. The labour and feed cost elasticity was inelastic but significant in all the equations. The purchasing price elasticity of day old chicks was 9.142. The disease cost elasticity was 3.265 in the grower equation. The supply elasticity of eggs was 2.562. This result showed that increase in the price of eggs for the small poultry producers was the best policy alternative available to convert this important livestock enterprise in to a profitable venture.

INTRODUCTION

In 1983 the total poultry population of Kandy district was 460,800 which represented 7.1% of Sri Lanka (Department of Census and Statistics, 1985). This was distributed among 231,809 small holdings and 91,998 labour sectors. Majority of them reared poultry under range (extensive) management system whereby the birds were allowed to roam during the day in the homestead in search of feed. The additional feeds were in the form of household refuse such as left over cooked rice, coconut refuse, rice bran, broken rice, and crop refuse. Most of the egg production were at the subsistence levels without surplus for marketing. This may be related to physical, socioeconomic, human and organizational factors in farming. The absence of secondary data on poultry farming in the district was a major setback of the poultry industry.

The main objective of this was to study the supply response of egg production of the backyard poultry farms in five assistant government agents divisions AGA of Kundasale, Patha Hewaheta, Udu Dumbara , Gangaihala and Minipe in Kandy district. The methodology included the estimation of supply response for poultry. The supply elasticities would be helpful in long term policies in poultry industry that may be necessary for egg production and enhancing the income among the farmers in the backward areas of Kandy district.

DATA COLLECTION

The primary data was collected from a field survey in the AGA divisions. From each AGA division 2-3 backward Agrarian Service Center divisions ASC was selected as ascertained by the average income levels, employment patterns, and housing. From each of these ASC divisions 9-10 cultivation officer regions were selected randomly. The poultry producers with single or multiple livestock enterprises in the selected cultivation officer CO regions was identified. A random sample of the 25 poultry farmers was selected from each AGA division for a total of 125 farmers from the five AGA divisions. A pretested questionnaire was used for the collection of the data by personal interviews.

METHOD OF ANALYSIS

The production of eggs from poultry involves a sequence of three stages at which key functions are performed.

The primary breeder flock, chicks of less than 2 months of age form the first stage. The chicks are fed to form the growers of 2-5 months. The growers beyond 5 months of age becomes the layer flock. The layer flock produces eggs for human consumption. The supply response model was investigated at these three stages. The supply of chicks reared determines the number of growers. The layer (or production) stage was affected by the survival of the growers. The decisions on feeds, diseases, labour, management at each stage depends on the current socioeconomic situation and on the decisions made at the earlier stage. The influence of previous stage involves technical or biological input-output relationships. The knowledge of technology characterizing the production is therefore crucial in specification of the model. For example, egg production follows a 12-14 month cycle characterized by a low laying rate, then a peak production, followed by slow decline. However the absence of time series data in poultry in Sri Lanka prevents the analysis such sequences that are characteristic in egg production.

The costs of feeds, labour, diseases, management, price of eggs, were the main economic variables affecting the supply response of poultry. The prices was deflated by using the consumer price index for foods as published by the Central Bank of Sri Lanka for 1988.

i) Chick Equation

CHK = f (MS, FPC, DCC, LABC, PCK) (1)

ii) Grower Equation

GRW = f (MS, LABG, FPCG, DCG, CHK) (2)

iii) Egg Production Equation

PRD = f (MS, LABL, FPCL, PE, CHK, DCL, LAYER) (3)

iv) Identity Equation

AYIELD = PRD / LAYER (4)

where,

CHK = number of chicks (poults) reared/farm;

MS = dummy variable for the level of management

MS = 1 for deep litter

= 0 for range management;

FPC, FPCG, FPCL = feed costs of chicks, growers, layers (Rs/farm);

LABC, LABG, LABL = labour costs of chicks, growers, and layers respectively (Rs/farm);

PCK = purchase price of chicks (Rs/chick);

DCC, DCG, DCL = disease prevention costs of chicks, growers and layers respectively (Rs/farm);

GRW = number of growers per farm;

PRD = daily total production of eggs/farm;

LAYER = number of layers/farm

PE = price of eggs (Rs/unit);

AYIELD = daily average layer egg productivity

The structure of the model form was linear. This simple specification was on the basis of little a priori information available concerning alternative functional forms. The inclusion of feed, labour, and disease costs may induce problems of multicollinearity in to the model. However labour, disease were typically variable inputs in egg production implying that their industry supply functions were not perfectly inelastic. The output supply functions are not homogenous of degree zero in prices (Silberberg, 1981,). Hence the price and costs were in the linear form rather than ratio form in the model. The labour and feeds were fitted as costs in the production model as any alternate forms provided inaccurate results. As the stages of egg production from poultry are sequential decisions made in one stage may affect the production of the other. Thus estimation of such a model by Ordinary Least Squares may lead to simultaneous biased estimates. Hence a Multivariate Regression technique of Zellner's Seemingly Unrelated Regression (Theil, 1971 Kmenta, 1971) was used for the estimation of the above model.

RESULTS AND DISCUSSION

The major purpose of rearing poultry in the farms was for egg production. In Kundasale, Patha Hewaheta, Udu Dumbara, and Gangaihala less than 9% of the farmers reared poultry for both eggs and broiler production. Nearly 45% of the poultry farmers in

Kundasale, Gangaihala and Minipe adopted an intensive poultry management or deep litter system. The other farmers rely on the extensive system due to the absence of continuous family labour and feed supplies.

The poultry for egg production ranges from local, white leghorn, brown leghorn or hybrids e.g. Row whites, Babcock etc; The type of birds in farms were either chicks, growers, layers, broiler starters, or broiler finishers. The white leghorns was also a popular breed among the farmers. The brown leghorn was reared by 9% of the farmers in Gangaihala. Of the hybrids Row white, and Babcock also were common. Rhode Island Reds (R.I.R) were reared by 3% of the farmers in Udu Dumbara. A higher proportion were layers as compared to the number of chicks, and growers.

The purchase of chicks by farmers was important as this was a parameter that shows the nature of poultry production in the farms. The success of poultry production also depends on the quality of the chicks purchased by the farmers. The purchased stock was either day old or mature birds. The chicks purchased from franchise agents and government farms were day old hybrid chicks. Most of the mature birds obtained by the farms were from the neighbouring farms or from the government farms. In general, the day old hybrid chicks from the franchise agents were expensive as they were from recently imported parent stocks. Most of the farmers complained that they were forced to wait for long periods before receiving the ordered chicks. Some of the farmers cited that the chicks distributed were weak and hence resulted in high mortality rate. As most of the farmers purchased their chicks from various sources it was difficult to maintain a uniform quality of the day old chicks.

The supplementary feeding of poultry was common in addition to extensive feeding. The type of supplements included commercial feeds, home mixed feeds, broken rice , and home refuse which included coconut refuse, rice bran , broken rice, and left over cooked rice. In all the AGA divisions majority of the farmers provided commercial feeds to the layers to increase egg production. The prices for commercial feeds varies from Rs. 5.56-6.80/kg. However the farmers with extensive management did not follow any systematic supplementary feeding system. Some purchased broken rice from rice mills at prices ranging from

Rs. 2.50/kg in Minipe and Kundasale to Rs. 4.10/kg in Gangaihala and Udu Dumbara. Most of the farmers purchased their commercial feeds from private traders. All the farmers cited the high prices of the commercial feeds as one of the major constraints in poultry production. The other problems included supplies not available on time and transport difficulties of farms. As most of the raw materials required for commercial poultry feeds were imported, the prices of feeds were high in the domestic markets and this could increase further in the future. Suitable research on feed formulation with locally available feed ingredients is imperative for the growth of the local poultry industry.

Except in Kundasale and Udu Dumbara more than 86% of the farmers used family labour for their poultry production. In Kundasale, nearly 12% of the farmers utilized hired labour. Most of the daily activities were managed by family labour e.g. feeding, water, gathering of birds for the night, collection of eggs, marketing. The hired labour was more involved in operations such as litter management, repairs to housing, security against theft. The amount of hired labour was from 117 mandays/farm in Udu Dumbara to 488 man days/farm in Kundasale.

The average number of layers in the AGA divisions varies from 12.8/farm in Udu Dumbara to 54.5 birds/farm in Gangaihala. The average daily production of eggs was from 17.2 eggs/farm in Udu Dumbara to 74.4 eggs /farm in Kundasale. The estimated number of eggs in the laying period of 9 - 12 months ranges from 3768.5/farm in Minipe to 12202.1 eggs/farm in Kundasale. These results indicated that the average egg production in the farms were low and variance among farms was high due to differing levels of management.

Most of the eggs produced in the farms were sold. The sources were mainly neighbouring farmers and traders from the villages. The prices offered by the traders were higher. Most of the farmers were satisfied with the existing marketing of eggs as they were small producers. However most of the farmers cited the low prices of eggs and high flexibility due to the influence of the large poultry producers as a major constraint.

SUPPLY RESPONSE MODEL

The supply response for egg production consisted of equations for chicks, growers, and egg production in the farm with the average layer productivitiy as an identity equation. Due to the presence of endogenous variables on the right hand side of the equations the Zellners Seemingly Unrelated Regression was used as the estimation procedure. The results are presented in table 1.

In the chick equation, all the variables have the expected signs and coefficients for labour and feed costs were significant. Thus an increase in the labour and feed costs by 10% would reduce the chicks reared in the farms by 3.6%, 5.6% respectively. As labour used in the farms for poultry production was family labour, included in the equation was the opportunity costs of labour in poultry production. As poultry production was low, most of the farmers used minimum labour for poultry compared with other farm enterprises. This may explain the inelastic cost share elasticity of labour in the farms. The feed costs were the highest among other input costs. This may be related to the higher prices of the commercial feeds. Consequently most of the farmers adopted extensive management system.The price of chicks from franchise agents and government farms were too expensive. For example, an increase in the price of chicks by 1% would reduce the number of chicks reared in the farms by nearly 9.1%. Hence most of the farmers purchased their day old or mature birds from the neighbouring farmers.

In the grower equation, all the coefficients has the expected signs with labour and feed costs being significant. The number of growers reared by the farmers was elastic with respect to labour feed and disease costs. An increase of disease costs by 1% would decrease the number of growers reared by nearly 3%. However diseases was not a major constraint of poultry production. The mortality of growers was mainly due to diarrhoea. For feed costs the major component was for the use of commercial feeds for growers. The results indicated that an increase of feed costs by 1% would reduce the number of growers in the farms by nearly 9%.

In the production equation, all the variables was of the correct sign. The coefficients for feed costs, labour costs price of eggs, and number of layers were significant. The price elasticity of eggs was 2.56 indicating that an increase of egg prices by 10% would increase the production of eggs by 21%. This result indicated that the higher price of eggs would be the best incentive for farm egg producers. Majority of the farmers indicated that the market prices of eggs were generally low as fixed by the bigger producers. The bigger producers could sell their farm eggs at a lower price due to the lower costs incurred due to their high scale of production. The marketing of eggs by Poultry Producers Association could create a competitive environment to improve the prices of eggs for the small producers. Alternatively, the formation of oligopolistic egg market with the price leadership to the bigger producers could improve the pricing structure of the small poultry farmers. The output-cost elasticity for labour, and feeds were inelastic in the results. For example, an increase in the feed costs by 10% would improve the eggs produced in the small farms by nearly 1.2%. A similar increase in the labour costs would increase production by nearly 1%. An increase in the number by 10% would increase the production by nearly 0.7%.

POLICY IMPLICATIONS

The high feed cost was a major constraint for poultry production in the five AGA divisions in Kandy district. Further research on feeds needed to reduce the prices of commercial feeds. The backyard poultry producers practised range management system due to expensive feeds, and farm labour supplies. This may also be related to the local breeds reared by majority of the farmers. The high prices of the day old hybrid chicks from franchise agents and government farms may hinder the higher egg productivity in the small holder farms. The purchase of day old chikcs from different sources was a major cause of the mortality of the chicks in the farms. The distribution of quality inspected day old chicks from good parent stock at a subsidised price may be an incentive to the poultry industry. The low farm gate prices of eggs could be overcome by improving the market share of the small egg producers. This may be done through the formation of Poultry Producers Association to handle all input and marketing services for the smaller farms. Alternatively the market structure may

Table 1 Estimates of the Structural Model of Egg Production.

i) Chick Equation

$$CHK = 18.2463 + \underset{(2.721)}{22.7683^{**}\,MS} - \underset{\substack{(2.311)\\((0.3598))}}{0.0136^{**}\,LABC} - \underset{\substack{(1.807)\\((9.1423))}}{0.3456\,PCK}$$

$$- \underset{\substack{(2.644)\\((0.5635))}}{0.0212^{**}\,FPC} \qquad R\ sq = 0.495$$

ii) Grower Equation

$$GRW = 5.3099 - \underset{(1.152)}{4.3517\,MS} - \underset{\substack{(2.508)\\((1.4928))}}{0.0094\,LABG} + \underset{\substack{(1.044)\\((4.9390))}}{0.0311\,CHK}$$

$$- \underset{\substack{(3.565)\\((9.0046))}}{0.0567^{**}\,FPCG} - \underset{\substack{(0.601)\\((3.2652))}}{0.0206\,DCG} \qquad R\ sq = 0.564$$

iii) Egg Production Equation

$$PRD = 77.4033 + \underset{(1.100)}{310.0338\,MS} + \underset{\substack{(1.948)\\((0.1340))}}{2.6575\,CHK} + \underset{\substack{(2.415)\\((0.0100))}}{0.1991^{*}\,LABL}$$

$$+ \underset{\substack{(2.961)\\((0.0169)}}{0.3362^{**}\,FPCL} - \underset{\substack{(0.179)\\((0.0238))}}{0.4724\,DCL} + \underset{\substack{(3.300)\\((2.5624))}}{50.8142^{**}\,PE} + \underset{\substack{(4.736)\\((0.0785))}}{0.8673^{**}\,LAYER}$$

$$R\ sq = 0.667$$

Figures in parentheses are the t values and in double parentheses are the elasticities at the mean of the variables concerned

* - significant at 5% level

** - significant at 1% level.

be oriented to form oligoplistic characteristics with the major egg producers occupying a price leadership in the egg market.

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PLANT GROWTH, NITROGEN FIXATION AND SEED YIELD RESPONSE OF TEN COWPEA (*VIGNA UNGUICULATA* (L.) WALP.) CULTIVARS TO INOCULATION WITH *BRADYRHIZOBIUM* AND ENDOMYCORRHIZAL FUNGI.

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ABSTRACT

Interaction between inoculation with *Bradyrhizobium* and endomycorrhizal fungi *Glomus fasciculatum* in ten cowpea cultivars was evaluated in a field experiment. Cowpea cultivars were grown in three soil treatments including, fumigation with methyl bromide (F), inoculation with *G. fasciculatum* after fumigation (GF), and natural soil (NS) which is not fumigated or inoculated and contain native mycorrhizal fungi and *Bradyrhizobial*, with and without bradyrhizobial inoculation. Shoot growth of cowpea was affected by the triple interaction between soil treatment, bradyrhizobial inoculation and cultivar. In most cultivars shoot dry weight was reduced in GF treatment compared to F treatment when grown without bradyrhizobial inoculation. Inoculation with strains SLM 504, 604 and 613 of *Bradyrhizobium* was helpful in recovering the shoot dry weight lost and in most instances it also increased the shoot dry weight in GF over F. Bradyrhizobial inoculation, therefore, was identified as a factor that can alter response to VA mycorrhizal fungi in a given cultivar. Soil fumigation reduced all N_2 fixation variables measured. Inoculation with *G. fasciculatum* after fumigation did not lead to the recovery of reduced N_2 fixation. This may have been due to poor adaptability of this inoculum to the new soil and environment. Cultivar plays an important role in the cowpea-mycorrhizal-bradyrhizobial symbiosis. Careful selection of cultivars is necessary to maximize the benefits obtained from beneficial microorganisms existing in local soil. Seed yield of cowpea was influenced only by the cultivar.

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is one of the major legumes cultivated in both tropical and subtropical regions of the world. Under low input agriculture systems, as mostly encountered in developing countries, legumes present a special case, because their capability of symbiotic N_2 fixation as well as formation of vesicular arbuscular mycorrhizae (VAM). For developing nations in the tropics, the process of symbiotic N_2 fixation is of special significance due to the high cost of synthetic N fertilizer. Mycorrhizae, on the other hand, assist plant growth in number of ways, primarily by facilitating absorption of P and other nutrients from the soil under low soil fertility levels (Mosse 1981), and thus reduce the cost of P fertilization.

Maximum benefit from mycorrhizae in agricultural systems could be obtained by inoculation with most efficient VAM fungi under given conditions and/or by maximum utilization of the indigenous mycorrhizal fungi. Application of the current VAM technology, which is mostly associated with the former approach, is presently limited by problems in mass inoculum production due to the inability to culture VAM fungi axenically and post-inoculation problems such as poor survival ability and competition from other soil microfauna. Until these constraints associated with application of current VAM technology are resolved, the second approach remains most practical. The efficiency of indigenous population of VAM fungi as well as *Bradyrhizobium* could be increased by selection of crop plants and their cultivars which can derive the most benefit from these microsymbionts.

Cowpeas are known to respond to inoculation with *Bradyrhizobium* (Eaglesham et al 1977, Oloke & Odeyami 1988) as well as VAM fungi (Islam et at 1980). The relative response of cowpeas to each of these two symbiotic relationship could markedly be affected by the cultivar used (Zary et al 1978, Rajapakse & Miller 1987, Ollivier et al 1983). Cultivar variability for cowpea-*Bradyrhizobium* symbiosis has been studied extensively for cultivars grown in USA (Zary et al 1978, Walker 1983). Intraspecific variability for VAM symbiosis has been studied in cowpea using two cultivars. Inoculation of two cowpea cultivars with VAM fungi *Glomus epigaeum* Daniels & Trappe stimulated growth of one cowpea cultivar, but not in other (Olivier et al 1983). Rajapakse & Miller (1987) inoculated two cowpea cultivars with *G. mosseae* (Nicholson and Gerdemann) Gerdemann & Trappe and *G. fasciculatum* (Thaxter sensu Gerdemann) Gerdemann & Trappe and demonstrated that influence of VAM fungi on shoot dry weight and nitrogenase activity was dependent on species of VAM fungi as well as host cultivar. *Glomus fasciculatum* was found to be more effective than *G. mosseae*. In a field experiment conducted with cowpea cultivars grown in USA, intraspecific variability in response to inoculation with *G. fasciculatum* has been studied extensively (Rajapakse et al 1989). Cowpea cultivars exhibited differential response and cultivars with good response have been identified. No broad study on cultivar variability for VAM symbiosis has been conducted with tropical cowpea cultivars.

The purpose of present investigation was to screen cowpea cultivars grown in Sri Lanka for their response to inoculation with *Bradyrhizobium* and *G. fasciculatum* under local field conditions.

MATERIALS AND METHODS

This field experiment was conducted at the University of Peradeniya farm at Dodangolla, Sri Lanka, where the mean temperature was 25^{o} C, elevation was 425 m and annual rainfall was 250 cm. Soil at the experimental site was low in N and had 15 ppm P (Sodium bicarbonate extraction) with a pH of 4.8.

Eight cultivars commonly grown in Sri Lanka and two USA cultivars were used in this study. Cultivar names and characteristics are given in Table 1. Cultivar MI 35, which was developed at the Maha Illuppallama Regional Agricultural Research Station is the most popular cultivar among local farmers. SEL 230-2, SEL 266-1 and SEL 75 are selections of MI 35. Sudu Mung is a traditional cultivar grown in Sri Lanka. Bombay Cowpea, EG No. 2 and and Arlington have been introduced to Sri Lanka from India, Philippines and USA, respectively and now grown in Sri Lanka. Mississippi Silver and Brown Crowder are US cultivars grown in Sri Lanka for the first time for this experiment.

Soil fumigation was carried out with methyl bromide (ai=100%) at the rate of 112 kg/ha. Fumigated plots were well disced and left for 2 weeks before planting. Seed of bradyrhizobial treatment was treated with a peat based inoculum which consisted of 3 strains, SLM 504, SLM 604 and SLM 613. Inoculum of *G.fasciculatum* was prepared in *Sorghum bicolor* (L.) Moench. pot cultures in a greenhouse at the Texas A&M University and was transported to Sri Lanka in sealed polythene bags. The mixed inoculum contained approximately 52 spores/100 g and 40 g of this inoculum was applied to planting holes at the time of seeding.

Plants were grown in rows in 1.8 m wide raised beds. One bed was used for each bradyrhizobial inoculation and soil treatment combination and replicated thrice for a total of 18 beds. Cultivar seeds were planted 30 cm apart on 0.5 m wide rows across beds, with guard rows planted at edges of each bed. Overhead irrigation was applied once. Manual weed control was practiced in nonfumigated plots.

The experimental design was a split-split plot with 3 blocks, with bradyrhizobial inoculation (inoculation and no inoculation) as the main plot, soil treatment (fumigation with methyl bromide (F), inoculation with *G.fasciculatum* after fumigation (GF) and no fumigation or inoculation with VAM fungi (i.e. untreated soil containing indigenous VAM fungi and *Bradyrhizobium*) (NS) as the sub plot and cowpea cultivar as the sub sub plot.

After 8 weeks, two plants from each cultivar in each replicate were harvested and plant height, shoot fresh weight, shoot dry weight (70^{o}C, 24 h), nodule number, nodule weight (70^{o}C, 24 h) and air dried root weight were measured. Nitrogenase activity of theses plants measured as described by (Zary et al 1978). The remaining plants in each row were allowed to grow up to 10 weeks, when pod number and seed weight were recorded.

Analysis of variance was performed to test the significance of the treatments, and LSD tests were conducted to compare treatment means.

Table 1 Description of cowpea cultivars used

Cultivar	Origin	N_2 fixation potential	Growth habit	Days to maturity	
				Dry[a]	Wet[a]
Sudu Mung	Sri Lanka	Low	Indeterminate	77	80
SEL 230-2	Sri Lanka	Low	Determinate[b]	65	72
SEL 266-1	Sri Lanka	Low	Determinate[b]	67	71
MI 35	Sri Lanka	Medium	Determinate	60	70
SEL 75	Sri Lanka	Medium	Determinate[b]	65	71
Bombay Cowpea	India	Medium	Determinate[b]	72	77
Arlington	U.S.	Medium	Determinate	67	73
Mississippi Silver	U.S.	Low	Indeterminate	71	71
Brown Crowder	U.S	High	Indeterminate	85	85
EG No. 2	Philippines	High	Determinate[b]	76	71

[a]Dry and wet seasons.

[b]Determinate but under very wet conditions indeterminate characteristics observed.

RESULTS AND DISCUSSION

Results of the analysis of variance are summarized in Table 2. Shoot fresh weight, shoot dry weight, and nodule number were affected significantly by the triple interaction between bradyrhizobial inoculation (BI), soil treatment, and cultivar. Cowpea cultivars showed differential response to soil treatments for nodule number and to BI for all plant growth variables as well as nitrogenase activity. The effect of cultivar was significant for all variables measured, and seed yield was influenced only by cultivar. The BI and soil treatment interaction was significant only for nodule number. Only the N_2 fixation variables were significantly affected by soil treatments. Inoculation with *Bradyrhizobium* significantly influenced all plant growth and N_2 fixation variables except seed yield.

Shoot growth of cowpea was affected by the triple interaction between soil treatment, bradyrhizobial inoculation and cultivar (Table 2). In order to compare growth of different cultivars, plant growth in the NS and GF treatments was calculated as a percentage of growth in F treatment, for the 2 levels of BI treatment (i.e. inoculation and no inoculation) (Table 3). Percent growth difference between mycorrhizal and nonmycorrhizal plants has been termed Mycorrhizal Dependency (Gerdemann 1975). It is not appropriate to call percent growth differences in NS treatment compared to F treatment in this experiment as mycorrhizal dependency, because of differences other than VAM fungi between NS and F treatments. Soil fumigation can destroy organisms other than mycorrhizal fungi, such as, pathogenic microorganisms, nematodes, insect pests and weeds (Maw and Kempton 1973). Soil fumigation can also leave residual chemicals in the soil. However, percent growth differences between GF and F treatments could be considered as mycorrhizal dependency since the only difference between these two treatments is the addition of *G. fasciculatum* to the GF treatment. Shoot dry weight data were used to calculate percent growth.

Table 2 Summary of the Analysis of Variance for Treatment Effects on Growth, N_2 Fixation and Yield of Cowpea

	Significance level						
Variable	BI[a]	S[b]	BI*S	C[c]	BI*C	S*C	BI*S*C
Plant growth:							
Shoot fresh wt	0.05	ns[d]	ns	0.001	0.001	ns	0.05
Shoot dry weight	0.05	ns	ns	0.001	0.001	ns	0.05
Height	0.05	ns	ns	0.001	0.001	ns	ns
Root weight	0.05	ns	ns	0.001	0.01	ns	ns
N_2 fixation:							
Nodule number	0.05	0.001	0.01	0.001	ns	0.05	0.05
Nodule weight	0.05	0.01	ns	0.05	ns	ns	ns
Nitrogenase activity	0.05	0.05	ns	0.05	0.05	ns	ns
Yield:							
Pods per plant	ns	ns	ns	0.001	ns	ns	ns
Seed weight per plant	ns	ns	ns	0.05	ns	ns	ns

[a]BI = Bradyrhizobial inoculation with strains SLM 504, 604 and 613.

[b]S = Soil treatment

[c]C = Cowpea cultivar.

[d]ns = Not significant at 0.05 level

Almost all cultivars had reduced shoot dry weight in the GF treatment when grown without bradyrhizobial inoculation, as indicated by percent growth values less than 100 (Table 3). Since this experiment was conducted in N deficient soil, growth of cowpeas were dependent on the biologically fixed N. The reduced shoot dry weight in the GF treatment could be due to the lack of biological N_2 fixation as there were no bradyrhizobia, either indigenous or inoculated, were present in the GF treatment. Presence of VAM fungi under such stressful conditions could place the host plant at an disavantage, due to the drain of organic C from the plant to the VAM fungi. Low percent growth values in the GF treatment was improved by inoculation with *Bradyrhizobium* in most cultivars, including Sudu Mung, MI 35, SEL 230-2, Brown Crowder, Bombay Cowpea and SEL 266-1. By addition of bradyrhizobial strains, mycorrhizal plants have increased shoot dry weight to a greater extent than nonmycorrhizal plants in these cultivars. Inoculation with *Bradyrhizobium* may have provided the plants with additional N from the atmosphere and assisted in deriving benefit from mycorrhizae. This cannot be confirmed since N content in the plants was not measured. Bradyrhizobial inoculation, therefore, was identified as a factor that can alter mycorrhizal dependency in a given cultivar, in addition to soil P level (Asimi et al 1980, Crush 1974, Daft and Nicholson 1966), soil type (Mosse 1972) and species of VAM fungi (Mosse 1972). In the NS treatment, where native bradyrhizobia were present, inoculated bradyrhizobia have increased percent growth only in some cultivars, including Sudu Mung, MI 35, Arlington and SEL 266-1. This indicates that in these cultivars, inoculated bradyrhizobial strains have increased growth in NS treatment to a greater extend than that in F treatment. Presence of mycorrhizal fungi and other microorganisms in the NS treatment may have increased the activity of inoculated strains of *Bradyrhizobium* or residual effects of fumigation may have reduced the activity of inoculated strains of *Bradyrhizobium* in F treatment. In SEL 230-2, Mississippi Silver, SEL 75 and EG No.2,

Table 3. Percent growth (PG)[a] of cowpea cultivars under natural soil (NS) and inoculation with *Glomus fasciculatum* after fumigation (GF) compared with fumigated plots (F) as affected by bradyrhizobial inoculation (BI).

Cultivar	NS		GF	
	No BI	With BI	No BI	With BI
Sudu Mung	73 b[b]	323 a	60 b	228 a
MI 35	102 b	147 a	57 b	138 a
SEL 230-2	215 a	91 b	69 b	136 a
Brown Crowder	112 a	96 a	56 b	114 a
Arlington	122 b	150 a	161 a	102 b
Bombay Cowpea	84 a	91 a	46 b	98 a
Mississippi Silver	84 a	36 b	77 a	81 a
SEL 75	122 a	36 b	91 a	77 a
EG No. 2	132 a	71 b	70 a	67 a
SEL 266-1	71 b	104 a	17 b	43 a

[a]PG = (Shoot dry weight of plants in either NS or GF/Shoot dry weight of plants in F) x 100.

[b]Mean separation between two columns of NS and between two columns of GF.
Means followed by same letter do not differ significantly by LSD test, at 0.05 level.

inoculated strains have reduced percent growth of NS over F. Inoculated bradyrhizobial strains have increased growth in F to a greater extend than that in NS. In these cultivars inoculated strains may have been competitive with local strains. Host plant may affect the competitiveness between strains of bradyrhizobium (Moawad et al 1988). In Brown Crowder and Bombay Cowpea, inoculated strains caused similar growth changes in both NS and F treatments. Nodule number was affected by the triple interaction similar to the shoot growth (Table 2).

The bradyrhizobial inoculation and cultivar interaction was significant for shoot fresh and dry weight, height, root weight and nitrogenase activity (Table 2). The interaction for nitrogenase activity is presented in Table 4. Cultivars SEL 230-2 and SEL 266-1 had high levels of nitrogenase activity with native bradyrhizobia and BI reduced the efficiency of native bradyrhizobia. For all other cultivars, inoculation with bradyrhizobial strains SLM 504, 604 and 613 increased nitrogenase activity over that produced by native bradyrhizobia alone. Cultivars MI 35, Sudu Mung and EG No. 2 showed high response to introduced Bradyrhizobium , while the response of other cultivars was less pronounced. This indicates that different bradyrhizobial strains are preferred by different cowpea cultivars, or an increased or reduced effeciency when both native and inoculated bradyrhizobia are present. Vincent (1981) reported that it is unusual for one rhizobial strain to be fully effective with all of the cultivars that it nodulates. The strains of bradyrhizobia native to the soil was not identified. Although nitrogenase activity is a one time, indirect measurement of N_2 fixation, the interactions observed between bradyrhizobial strains and cultivars shed some light over the shoot dry weight responses observed in the NS treatment described previously.

Table 4 Influence of Bradyrhizobial Inoculation on Nitrogenase Activity[a] of Cowpea Cultivars.

Cultivar	Native bradyrhizobia only	Native + Inoculated bradyrhizobia	% Increase
EG No. 2	.273	2.800	925
MI 35	.148	1.295	775
Sudu Mung	.235	1.042	343
SEL 75	.681	1.764	159
Arlington	.818	2.823	123
Brown Crowder	.497	0.916	84
Mississippi Silver	.692	1.251	81
Mississippi Silver	.440	0.545	24
SEL 230-2	1.112	0.713	-36
SEL 266-1	1.363	0.393	-71

[a] $\mu M\ C_2H_4 .\ plant^{-1} .\ hr^{-1}$. Means of 3 soil treatments.

Nodule number, nodule dry weight and nitrogenase activity were reduced by the soil fumigation (Table 5). Inoculation with *G. fasciculatum* did not help in the restoration of the reduced N_2 fixation variables. This observation differs from that of a previous experiment conducted in USA, where the adverse effects of fumigation were at least partially overcome by inoculation with the same isolate of *G. fasciculatum* (Rajapakse et al, In review). The difference in the effectiveness of the same fungus to this environment and the difference in soil nutrient status between the two locations. However, loss of viability in the inoculum may have also contributed to the observed reduced effectiveness. Out of the 3 soil treatments, the greatest nodulation and nitrogenase activity was observed in the NS treatment across both levels of bradyrhizobial inoculation.

Table 5 Influence of Soil Treatments on Plant Variables.

Variable	Soil treatment		
	Natural soil	Fumigation	Inoculation with *Glomus fasciculatum* after fumigation
Shoot fresh weight (g)	64.78 a[a]	63.17 a	51.90 a
Shoot dry weight (g)	8.77 a	8.33 a	7.51 a
Height (cm)	24.40 a	22.90 a	18.60 a
Root weight (g)	4.22 a	3.70 a	3.41 a
Nodule number	16 a	10 b	11 b
Nodule dry weight (g)	0.112 a	0.028 b	0.016 b
Nitrogenase activity[b]	1.97 a	0.49 b	0.45 b
pods per plant	25 a	24 a	20 a
Seed weight per plant (g)	53.62 a	52.99 a	35.47 a

[a]Means followed by a common letter within rows do not differ significantly by LSD test, 0.05 level.

[b] $\mu M\ C_2H_4 . plant^{-1} . hr^{-1}$.

Inoculation with strains SLM 504, 604 and 613 of *Bradyrhizobium* significantly increased all plant variables measured except seed yield over that produced by native bradyrhizobia alone (Table 6). Number of pods and seed weight per plant were greater when inoculated with Bradyrhizobium; however, the differences were not significant at 0.05 level. The organic substrates produced by photosynthesis and N_2 fixation do not necessarily translocate to pods and seeds. The partitioning of C,N and other nutrients to the yield components can be more important than the increase in vegetative growth which does not necessarily result in increased yield. Native bradyrhizobia may be effective in diverting nutrients to the pods and seeds than inoculated strains. Evidence for the control of nutrient translocation within the plant by strains of *Bradyrhizobium* was not founds. Increased cowpea yield by inoculation with other bradyrhizobial strains such as, Ife CR9, Ife CR15 and *B. Japonicum* have been reported (Oloke and Odeymi 1988).

Table 6. Influence of Inoculation with *Bradyrhizobium* on Plant Variables.

Variables	Native bradyrhizobia		Native and introduced bradyrhizobia	
Shoot fresh weight (g)	44.3	b[a]	74.4	a
Shoot dry weight (g)	5.43	b	10.75	a
Height (cm)	17.50	b	26.30	a
Root weight (g)	3.07	b	4.41	a
Nodule number	10	b	15	a
Nodule dry weight (g)	.03	b	.076	a
Nitrogenase activity[b]	0.61	b	1.26	a
Pods per plant	21	a	25	a
Seed weight per plant (g)	40.7	a	54.3	a

[a]Means followed by a common letter within rows do not differ significantly by LSD test, 0.05 level.

[b]$\mu M\ C_2H_4 .\ plant^{-1} .\ hr^{-1}$

Cultivar plays an extremely important role in determination of growth, N_2 fixation and seed yield of cowpea (Table 7). In this study, cowpea yield was influenced only by cultivar (Table 2). Three US cultivars, Mississippi Silver, Brown Crowder and Arlington, showed moderate growth and nodulation, but produced the greatest pod number and seed yield. Arlington was introduced to Sri Lanka several years ago and is quite popular among farmers. The other two US cultivars were grown in Sri Lanka for the first time, but yielded well despite the change in soil and environment. Cultivar EG No. 2, which was introduced from Philippines, did not show much vegetative growth. It was the highest N_2 fixing cultivar used in this experiment, but produced only moderately high yield. Bombay Cowpea, a cultivar introduced from India, showed the greatest vegetative growth and nodulation, but yielded less than the US cultivars. Sri Lankan cultivars showed less growth, nodulation and seed yield relative to the introduced cultivars. Of the local cultivars, MI 35 produced the greatest yield. Cultivar MI 35 has an added advantage, as it can mature in 60 days and thus avoid late season drought.

Relatively few published reports of VA mycorrhizal field experimentation is available compared to the number of pot experiments, although there has been an upsurge in the reported field trials lately (Powell, 1984). This probably reflects the difficulties involved in field experimentation of VAM fungi. Due to the confounding effects from fumigation and other factors, satisfactory delineation of VAM effects is prevented in this experiment. Nevertheless it has been able to collect valuable information on tropical cowpea cultivar variability to *Bradyrhizobium* symbiosis. Cultivars MI 35, Sudu Mung and EG No. 2 have been identified as the most responsive to strains SLM 504, 604 and 613 of *Bradyrhizobium* while cultivars SEL 230-2 and SEL 266-1 had the greatest response to indigenous *Bradyrhizobium* . In order to get optimum results from field inoculation with VAM fungi, maintenance of viability of the VAM inoculum in the field and competition from other soil organisms should also be studied.

Table 7. Influence of Cultivar on Growth, N_2 Fixation and Yield of Cowpea

Cultivar	Shoot fresh wt (g)	Shoot dry wt (g)	Height (cm)	Root weight (g)	Nodule number	Nodule weight (g)	Nitrogenase activity[a]	Pods per plant	Seed weight (g)
Mississippi Silver	74.7 bc[b]	10.4 b	22.8 bc	4.4 bc	10 d	.046 bc	0.44 b	28.5 a	59.7 a
Brown Crowder	73.1 bc	10.0 b	18.2 ed	4.5 b	06 e	.058 abc	0.68 b	27.5 a	55.9 ab
Arlington	58.7 cd	7.2 cd	19.9 cd	3.9 bcd	14 bc	.43 bc	1.40 ab	27.8 a	54.2 ab
Bombay Cowpea	98.9 a	16.0 a	22.1 bcd	6.1 a	20 a	.098 a	0.86 b	21.3 b	53.5 ab
EG No. 2	37.2 e	4.3 ef	23.3 bc	3.3 d	15 bc	.063 abc	2.40 a	23.8 ab	47.6 ab
SEL 266-1	41.8 e	5.3 e	21.8 bcd	2.5 e	11 cd	.28 c	0.84 b	21.7 b	46.6 ab
MI 35	50.1 de	7.0 cd	21.5 bcd	3.5 cd	05 e	.036 bc	0.71 b	23.4 ab	46.1 ab
SEL 75	63.3 bcd	8.0 bc	15.8 e	3.8	18 ab	.076 ab	1.20 ab	19.3 b	39.5 b
Sudu Mung	77.7 b	10.6 b	27.7 a	3.5 d	17 ab	.055 abc	0.64 b	18.0 b	37.5 b
SEL 230-2	17.8 f	2.1 f	25.6 ab	2.1 e	11 cd	.032 bc	0.79 b	18.7 b	37.4 b

[a] $\mu M\ C_2H_4 \cdot plant^{-1} \cdot hr^{-1}$.

[b] Means followed by a common letter within the same column do not differ significantly by LSD test, 0.05 level.

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PRELIMINARY STUDIES ON DIVERSITY OF INSECT PESTS ON WINGED BEAN PSOPHOCARPUS TETRAGONOLOBUS (L.) DC

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SUMMARY

Preliminary studies on diversity of insect pests affecting winged bean Psophocarpus tetragonolobus (L.) DC. in Southern Florida, USA was investigated in two cultivation systems, from early stages growth of the plant using several sampling methods. Diabrotica balteata Lec., Nezara viridula (L.), Acrosternum marginatum (P. de B.), Empoasca spp and Platynopa rostrana Walker were the main leaf feeding pests in trellis system. Leptoglossus phyllopus (L.) densities were markedly higher in flowers in trellis system. N. viridula was found to be the only pest infesting the tender pods. The beneficials Hippodamia convergens Guer and Coccinella responda Thunburg were significantly higher in creeping system. However, no insect pest reached the status of a major pest warranting control strategies.

INTRODUCTION

The winged bean Psophocarpus tetragonolobus (L.) DC. is a climbing leguminosae perennial and has considerable potential to combat malnutrition. It is widely grown as a green vegetable, grain legume, tuber crop and as a forage and cover crop in Southeast Asia (Khan, 1982). The nutritional quality of winged bean is due to high protein content in its edible parts as in mature seed 20.7-45.9% (Hildebrand et al; 1982), tubers 8% (Cerny, 1978). Winged bean is well known in many countries in tropical belt but when National Academy of Sciences (NAS, 1975) recognized winged bean as a valuable protein source, its spread was rapid.

Winged bean has reported earlier as a relatively free from insect pests (Rachie and Roberts, 1974) but due to its rapid spread has accumulated several important insect pests (Abu and Karikari, 1978, Taborsky, 1982). The bean pod borer *Maruca testulalis* Geyer has been reported as an important insect pest of flowers and pods in Papua New Guinea (Lamb and Price, 1978). Rajapakse and Kulasekera (1982) showed *M. testulalis* and *Mylabris pustulata* Thunb. as main pests of flowers and pods in Southern Sri Lanka. The purpose of this investigation is to describe the main insect pests affecting the crop in Southern Florida in two cultivation systems.

MATERIALS AND METHODS

The experimental site (extent 0.40 hectare) was at University of Florida, Agric. Research and Education Center, Homestead, Florida on a Rockdale fine sand loam soil type with a pH range 7.5-8.0. The cultivars used were selections belonging to the Second International Winged Bean trial co-ordinated by Winged Bean Development Centre in Malaysia. Twenty-four selections of winged bean were used. The selections used were entries 12-02, 14-03, 27-02, 28-01, 46-03, LBN-C26C(T), LBN-C26V(B), LBN-C33P(C), LBN-C8HP(C), LBN-C8HH(C), UPS 62, UPS 102, UPS 122, GRWB 11, GRWB 26, SLS 40, SLS 47, BINH MINH, UPM 207, UPM 277, UPM 281, UPM 282, UPM 285, UPM 205. Seeds were planted on 22 March 1983 on rectangular hills covered with plastic mulch and were 1 m apart. The experiment design was Randomized Complete Block with 5 replications. Two different types of cultivation techniques were practiced. As winged bean is a twining climber, plant support was given in the form of inverted V trellis for several selections. The same selections were allowed to creep along the ground to facilitate two cultivation systems, where insect pests counts could be taken. The resulting stand densities for trellis system were approximately 0.5 m between plants/row. In trellis systems a standardized uniform trellis structure was used. Each hill had 4 stakes securely rammed into the ground at the corners adjacent to the planting position and tied near the top to form an elongated pyramid. The vertical distance between apex and the ground was 2 m. The trellises were uniform in size both within and between sites as crop performance could be influenced by the heights of the supports provided. The crop was irrigated regularly using a sprinkler irrigation system. Fertilizer was applied before planting at the rate of 32 kg/ha N, 64 Kg/ha P and 64 kg/ha K, and no insecticides or acaricides were used during the test period.

Abundance of Pests.

Sampling commenced 2-3 weeks after seed germination when the plants were about 35-45 m in height. Several techniques were used in the study to determine which species of insect pests were present and to gain information on variation of population density in the two systems of cultivations practiced. Eighteen plants selected at random were examined in the late afternoon for insect pests density. The plants in the two systems were examined visually for density estimates and population estimates in various plant parts such as mature and tender leaves, flowers and later pods were recorded. The presence of larval stages were determined by inspecting the damage from the leaves thredded together. The larvae were separated and head capsule width were measured on each sampling day. The plants were shaken vigorously to detect stink bugs. Ten samples per selection were carried out on each sampling day. After recording the data, some specimens were sent to Division of Plant Industry, Fla. Dept. of Agriculture, Gainesville for identification.

The cumulative mean number of insect pests in both systems were calculated and tested ANOVA based on weekly records of insects sampled.

RESULTS AND DISCUSSION

Diabrotica balteata, Empoasca spp, Nezara viridula, Acrosternum marginatum and Platynopa rostrana were the most common leaf feeding insects that were present in this study. The leaf feeding chrysomelid D. balteata reached 20 insects/sample on 2nd week of July in the plants grown in trellis system. D. balteata not only damaged the leaves by feeding directly on them but also transmit virus disease (Hobbs, 1981). A prominent yellow mosaic pattern representing a virus disease was observed in several selections implicating the possibility of D. balteata transmitting the disease. Populations buildup of D. balteata appeared to be related to the stages of growth of winged bean since population increased with increasing growth stages of the plants. The green bug N. viridula was present throughout the sampling period reaching two peaks on 3rd week of June and 4th week of May and then declined gradually. Initially, the population of Empoasca spp were found to be high (8 insects per sample) and reached another high peak at the conclusion stages of the study. The tortricid P. rostrana was present in low numbers throughout the experimental period. Leaves damaged by this tortricid larvae are thredded together which makes visual observation of larvae difficult. the Pentatomid A. marginatum was present damaging tender leaves in small numbers.

When the plants began to flower from first week of June, the coreid Leptoglossus phyllopus densities began to climb up from intiation of flower development. As the season progressed the densities gradually declined but had another peak on July 13 in plants grown in trellis system. Comparatively the initial densities in creeping system were significantly low but gradually increased reaching a peak on 8th July. However, the densities of L. phyllopus were markedly higher in selections grown in trellis system.

The pentatomid N. viridula was the only insect found infesting the newly emerged pods. The population of N. viridula reached a peak on 18 July and remained at relatively higher densities until 29 July, significantly different than on the counts of creeping system. Besides there was another significant difference on both systems on 2nd July and 29th July. The trellis system provided more space for vegetative growth of winged bean and N. viridula could easily hide among the thick vegetation and infests pods and leaves. Besides damaging the pods, the Pentatomid N. viridula and A. marginatum adults and nymphs were frequently observed on leaves during the sampling period. During late July several egg masses of stink bugs were observed but there was no indication that the resulting nymphs survived due to very low number of pods that were available. Although A. marginatum adults and nymphs were frequently seen on winged bean during June and July they were never numerous during early weeks of August. In fact, most of the A. marginatum observed June and July were maiting pairs. Nymphs of leaf footed bug L. phyllopus were even more abundant than A. marginatum and competition may have contributed to the decrease populations of A. marginatum nymphs.

The chrysomelid D. balteata was the most abundant pest present in cumulative mean numbers of pests recorded during the 12 weeks of sampling (Table 1). D. balteata, L. phyllopus, Empoasca spp and P. rostrana had significantly greater number of insects in plants grown in trellis system than the creeping system. For the 22 categories, 11 categories of creeping system showed a significantly ($P > 0.05$) greater number than trellis system. Of importance from both ecological and biological control context is the relative level of beneficial species. The coccinellids Hippodomia convergens and Coccinella responda were found most abundant in plants grown in creeping system than the trellis system. The prevalence of bean aphid Aphis craccivora in winged bean has been reported widely (Khan, 1982). However aphids were not observed throughout the experimental period probably due to the prevalence of these predatory coccinellids. Besides white plastic mulches are known to act as aphid repellents (Smith and Webb, 1969). Wyman et al; (1979) found a 96% reduction in aphid population on pumpkins mulched with white plastic. Incorporation of plastic mulch into our plots probably repelled aphids from establishing a population. The significant differences in cumulative mean numbers observed in the two systems practiced probably due to microclimatic differences such as wind movement, temperature and light intensity.

The tortricid P. rostrana larvae were observed in significant numbers in trellis systems and their abundance is shown in Fig. 1. A high number of small sized larvae were detected reaching a peak 27 May but the population gradually declined throughout the experiment period. However, the number of large larvae detected increased reaching a peak on 12 July.

Of the 22 arthropod categories represented, 18 were pest species or innocuous plant feeders and 4 were beneficials. Of interest is whether the density of the pest and the stage of crop growth affect the relative attractiveness of the two systems practiced.

Analysis of Table 1 showed that main pests of winged bean are attracted to the trellis system which is widely practiced than creeping system. However more pests are attracted to the creeping system because it covers a wide area than the trellis system. Attractiveness as affected by stage of crop growth is important because crop's susceptibility to pests may change as the crop matures. Coupled with the cultivation system practiced, the plants grown in creeping system has attracted more pests than the traditional trellis system as the crop matured. However, no pest reached that status of a major pest warranting control strategies in both systems. But it is postulated that with increase of acreage of cultivated winged bean, several pests such as D. balteata, P. rostrana and N. viridula has the possibility of becoming major pests of winged bean in Southern United States.

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Table 1. Cumulative Mean Number of Insects Recorded for Winged Bean.

Species	Age and Class[a]	Pest status[b]	Trellis system	Creeping system
Orthoptera				
Acrididae				
Melanoplus spp.	A	P	9.1	8.7 NS
Hemiptera				
Cicadellidae				
Oncometopia nigricans Walker	N,A	P	14.6	17.5 NS
Homalodisca coagulata Say	N,A	P	18.5	20.6 NS
Empoasca spp.			117.6*	98.5
Pentatomidae				
Nezara viridula (L.)	N,A	P	86.5	117.5*
Acrosternum marginatum (P. de B)	N,A	P	74.5	96.5*
Miridae				
Creontiades rubrinervis (Stal)	A	P	14.6	18.6 NS
Coreidae				
Leptoglossus phyllopus (L.)	N,A	P	152.7*	117.5
Lygaeidae				
Oxycareuus spp.	A	P	9.4	8.5 NS
Membracidae				
Spissistilus festivus Say	A	P	10.7	9.5 NS
Delphacidae				
Stobaera concinna (Stal.)	A	–	9.7	14.6*
Lepidoptera				
Tortricidae				
Platynopa rostrana Walker	L,A	P	69.5*	56.5
Platynopa flavedena Clemens	L,A	P	11.4	10.5 NS
Noctuidae				
Cobubatha quadrifera Zeller	A	–	4.6	6.1 NS
Pyralidae				
Hellula phidilealis Walker	A	P	14.9	20.7*

Table 1. Continued..

Species	Age and class[a]	Pest[b] status	Trellis system	Creeping system
Thusanoptera				
Thripidae				
Unidentified spp.	A	P	115.5	119.7 NS
Coleoptera				
Chrysomelidae				
Diabrotica balteata Lec	A	P	207.2*	117.01
Phyllotreta spp.	A	P	11.4	10.7 NS
Coccinellidae				
Hippodamia convergens Guer	A	B	107.9	156.9*
Coccinella responda Thunberg	A	B	101.7	111.2*
Hymenoptera				
Braconidae				
Cotesia marginiventries Cressan	A	B	14.2	11.5
Chelonus insularis Cressan	A	B	19.3	27.3*

$P < 0.05$ NS - Not Significant

[a]L: larva, N: Nymph, A: Adult

[b]P: pest B: beneficials

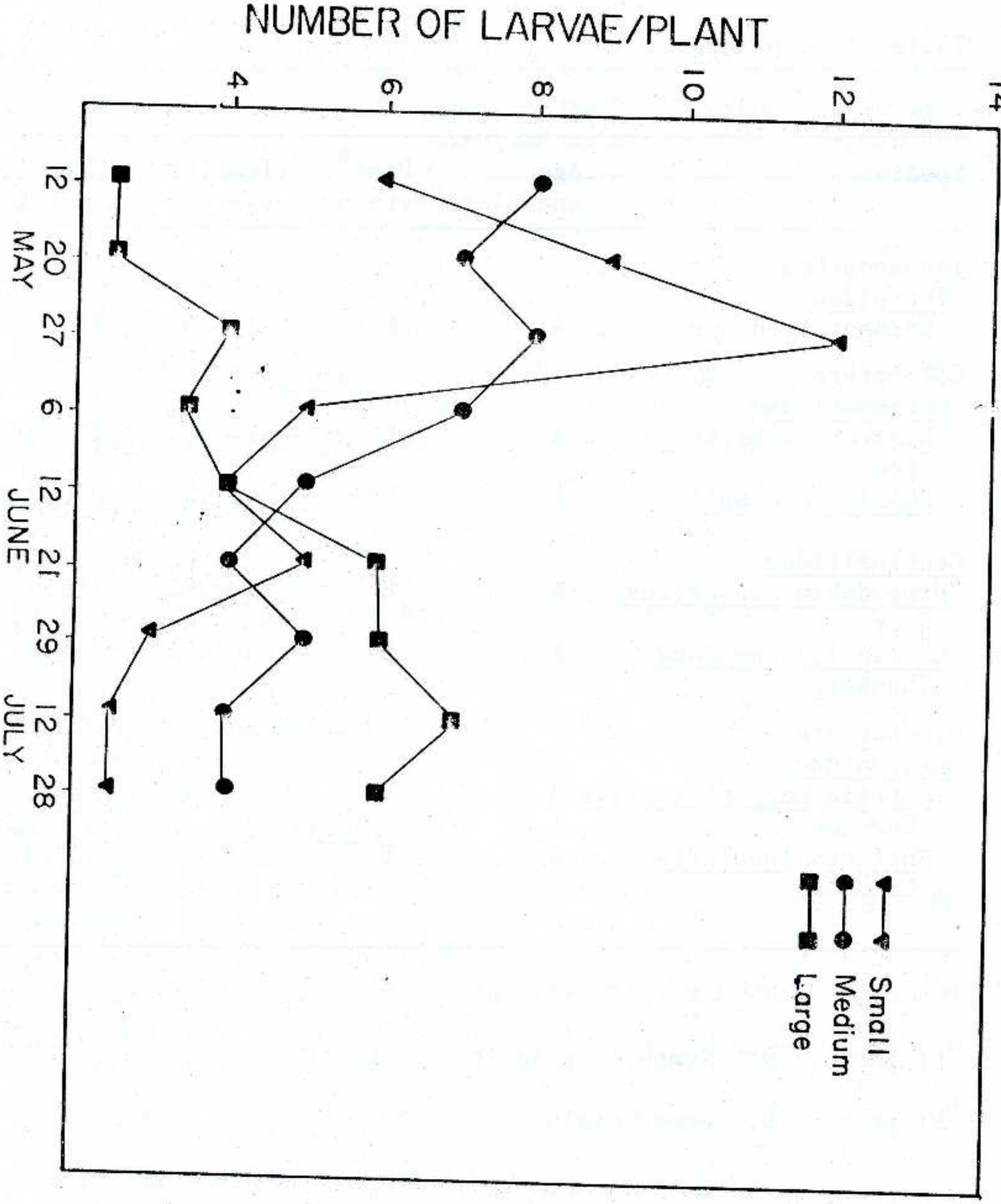

Fig. 1 Abundance of three larval sizes of Platynopa rostrana in trellis system. Size based on head capsule width Small < 0.6 mm Medium = 0.6-1.00 mm Large > 1.0 mm.

DINITROGEN FIXATION IN WINGED BEANS(*PSOPHOCARPUS TETRAGONOLOBUS(L)DC.*):

3. EFFECT OF DIFFERENT *RHIZOBIUM* STRAINS AND NPK-FERTILIZATION ON ONE WINGED BEAN SELECTION AT TWO SITES.

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SUMMARY

Winged bean selection SLS 44 was tested with four selected *Rhizobium* strains at two levels of NPK in two agro-ecological zones of Sri Lanka. Inoculation was done with single *Rhizobium* strains KUL-GP, KUL-JN, KUL-BH and TAL1022.

Differences due to strains were found. Some negative responses on inoculation were observed, mostly in the early stages. The most promising strains were KUL-GP and KUL-JN. Inoculation with these single *Rhizobium* strain was found to be comparable with 100 kgN/ha. KUL-GP was found to be tolerant to high levels of nitrogen. N increased the drymatter production and reduced the nodule formation with some strains. PK reduced the effect of inoculation for most strains, and improved the total plant yield and the percentage nitrogen but not significantly. However, the dose and the form of PK were suboptimal.

The results observed cannot be attributed to competitivity of the native strains alone. It was suggested that, among other factors, all nutrients are required to obtain optimal results in the host-symbiont relationship.

INTRODUCTION

In previous experiments (Van Holm and Moors, 1989) the effect of inoculation with one selected *Rhizobium* strain on different winged bean selections was tested at different agro-ecological sites.

In this study the effects of NPK and inoculation with single *Rhizobium* strains on the total dry matter yield and nodule parameters of a local winged bean accession SLS 44 were investigated under field conditions at two locations in Sri Lanka.

MATERIALS AND METHODS

Four dinitrogen fixing strains (Table 1) were tested SLS 44 at two sites, Meewatura and Pallekela (Table 2).

Table 1 : *Rhizobium* strains tested.

Strain	Original host	Origin	Institution
TAL-1022	*P. tetragonolobus*(L.) DC	Thailand	NifTAL
KUL-BH	*P. tetragonolobus*(L.) DC	Indonesia	K.U. Leuven
KUL-GP	*P. tetragonolobus*(L.) DC	Sri Lanka	"
KUL-JUN	*P. tetragonolobus*(L.) DC	Indonesia	"

The experimental design was a split-split-plot with 4 replicates with *Rhizobium* strains as main treatment; PK (two levels : 0,100 kg P and K/ha as rock phophat and muriate of potash) as sub treatment; control, 100 kgN/ha (as urea in 3 split applications) and inoculation with peat-based inoculant as sub sub treatments. The plot size was 3.5m x 1.5m. The experiment commenced in December 1983. All other experimental procedures were similar to those reported by the

Table 2 : Main Characteristics of Experimental Fields.

Site (1)	Agro-ecological Zone and Symbol		Annual rainfall	Soilgroup (2)	Altitude m
Meewatura	wet	mid(WM3)	1270	fluvent	488
Pallekela	interm.	mid(IM3)	889	eutropept	492

Source : T.M.K. Wijesinghe, 1979. Land and water use division, Dept. of Agric., Peradeniya, Sri Lanka.

(1) Meewatura Experimental Station, Fac. of Agric.,University of Peradeniya
International Winged Bean Institute, Pallekele, Kundasale.

(2) USDA Soil Taxonomy (Booker Tropical Soil Manual, 1984)

authors (1989). However, inoculation was carried out with a peat based inoculant according to the method described by NifTAL (Somasegaran and Hoben, 1985).

Plant samples were taken at two and four months after planting (MAP). The following data were recorded : total plant dry weight, total root fresh weight, N in the shoots (%), total nodule number, total nodule weight, weight/nodul.

Prior to the commencement of the experiments the soils were analyzed (Table 3). The pH of the soil was neutral and thus optimal for the establishment of *Rhizobium* (Deya et al., 1981; Iruthayathas, 1984). The percentage of carbon was very low at Meewatura. The amounts of available nutrients were low.

Tsble 3 : Soil Analyses (0-30cm) of the Experimental Sites.

Site	%N	P in ppm	%C	K in mg	Mg per 100	Ca soil	NH_4-N in ppm	NO_3-N	PH-H_2O
Meewatura	0.084	1.0	0.50	10.0	11.0	40.0	12.4	6.4	7.2
Pallekele	0.160	1.0	1.10	8.0	19.0	100.0	22.5	2.6	7.2

Table 4 . Climatic Data

Site	(a)	Nov.	Dec.	Jan.	Feb.	Mar.
		1973–1974				
Pallekelle	1	156	260	236	229	92.5
	2	29.4	28.4	28.4	26.6	30.3
	3	20.0	20.8	19.7	21.4	21.4
	4	5.6	3.9	3.9	4.0	7.0
Peradeniya	1	223	317	218	120	210
	2	25.0	26.9	27.5	27.9	30.1
	3	17.5	20.2	19.5	20.0	19.7
	4	5.8	5.2	4.3	3.8	6.6

(a) 1 : Rain fall, (mm)
2 : Maximum temperature, °C
3 : Minimum temperature, °C
4 : Bright sunshine, (hours)

RESULTS AND DISCUSSION

The total dry weight of plants at Meewatura at 2 MAP increased signficantly with added nitrogen (Table 5). Inoculation and PK had no significant positive effect. Inoculation with TAL1022 was significantly better than with KUL-BH. Strain KUL-GP and TAL 1022 increased the biomass production. The interactions were not significant.

The fresh root weight/plant was significantly higher in the N treatment and was reduced by inoculation (Table·5). There were no significant differences between *Rhizobium* strains or PK levels. No interactions were significant.

Nitrogen increased the total drymatter production significantly 4 MAP (Table 5). The addition of PK, though positive was not significant. Inoculation with strain KUL-GP and KUL-JN increased the biomass significantly in comparison with KUL?BH. The result was not significantly different from the N control. The effect of TAL 1022 was intermediate. Addition of PK was negative

Table 5. Effect of Inoculation, N and PK on the Total Plant Dry Weight and Root Fresh Weight/plant of Winged Bean at Meewatura.

Strain Treatment	2 MAP Tot. pl. dry weight g/m^2	2 MAP Root fresh wt. g	4 MAP Tot. pl. dry weight g/m^2	4 MAP Root fresh wt. g	4 MAP N yield g/m^2
TAL 1022	15.6^{a}		59.7^{ab}		6.87^{ac}
KUL-BH	12.2^{b}		47.2^{a}		4.99^{a}
KUL-GP	14.4^{ab}		78.6^{b}		9.95^{b}
KUL-JN	12.9^{ab}		73.0^{b}		9.50^{bc}
control	12.2^{a}	3.57^{ab}	54.5^{a}	7.79^{a}	6.31^{a}
N-fert.	17.3^{b}	3.88^{a}	84.9^{b}	10.59^{b}	9.82^{b}
Inoc.	12.2^{a}	3.36^{b}	53.9^{a}	8.24^{a}	7.29^{a}

Means in a same column and treatment group, followed by the same letter are not significantly different at 0.05 probability according to DMRT.

in the inoculated plots, especially with strain KUL-BH.

The root mass increased significantly with N (Table 5). Inoculation and PK had no significant effect.

The N-yield/m^2 at Meewatura 4 MAP, was not affected by the PK but significantly positive by inoculation with strain KUL-GP and KUL-JN and N fertilizer (Table 5).

The total plant dry weight at Pallekele (Table 6) at 2 MAP decreased significantly with inoculation. Effect of N and PK and *Rhizobium* strain was not significant. The root fresh weight increased significantly with PK, but decreased significantly with inoculation (Table 6).

The total plant dry weight at Pallekele at 4 MAP increased with inoculation and N, but not significantly (Table 6). PK decreased the biomass production. KUL-JN significantly increased the drymatter production, TAL 1022 recorded the lowest biomass.

The fresh root weight/plant was not affected by the treatments.

Table 6. Effect of Inoculation, N and PK on the Total Plant Dry Weight and Fresh Root Weight/plant of winged bean at Pallekele.

Treatment	2 MAP		4 MAP
PK Fertilizer	Tot. pl. dry weight g/m^2	root fresh wt. g	Tot. pl. dry weight g/m^2
Control	48.8[a]	9.07[a]	
N-Fert.	44.8[a]	8.69[a]	
Inoc.	35.8[b]	6.34[b]	
TAL 1022			105.5[a]
KUL BH			143.9[a]
KUL GP			167.3[ab]
KUL JN			224.7[b]
0 PK		7.26[a]	
100 PK		8.91[b]	

Means in a same column and treatment group,followed by the same letter are not significanly different at 0.05 probability according to DMRT.

The nodules/plant at Pallikel 2 MAP was not significantly influenced due to PK (Table 7). Differences between the strains were not significant. Inoculation decreased the nodul number significantly. N reduced nodule number though not significantly.

Table 7. Effect of Inoculation, N and PK on the Number of Nodules/Plant Nodule Dry Weight/Plant and Dry weight/ Plant and Dry Weight/Nodule of Winged Bean at Pallekele, 2 MAP.

Treatment	no. of nod./pl.	nod. dry wt./pl. (mg)	dry wt./nod. (mg
Control	28.9[a]		
N-Fert.	24.1[ab]		
Inoc.	22.4[b]		
TAL 1022		270.9[a]	11.1[a]
KUL-BH		347.3[ab]	12.9[a]
KUL-GP		434.1[b]	19.6[b]
KUL-JN		339.9[ab]	15.7[ab]

Means in a same column and treatment group, followed by the same letter are not significantly different at 0.05 probability according to DMRT.

The nodule weight/plant was significantly different among the strains (Table 7). KUL-GP had the highest nodule weight/plant, while TAL 1022 had the lowest. The weight/nodule was significantly higher for KUL-GP (Table 7). The effects of PK were not significant except for the root fresh weight at Pallekele at 2 MAP. A low soil phosphorus level (Table 3) and slow releasing rockphosphate may have resulted in a suboptimal effect in this short term experiment. Subba Rao (1976) and Hamdi (1976) indicated the need for high levels of phosphorus for improved results from inoculation with other legumes.

The relatively high K level in comparison with the level of other nutrients could depress the yield, probably due to a nutrient imbalance (Abdel-Wahab, 1986; Seneviratne and Keerthisinghe, 1989).

Positive effects of PK in combination with N, and in the control plots with native rhizobia were observed. An antagonistic effect with inoculation was observed. PK improved the N % in the plants in all treatments but, not significantly. Similar effects were found by Abdel-Wahab (1986), Seneviratne and Keerthisinghe (1989). PK decreased the nodule size and the vegetative production of the inoculated plots. A positive effect on the root development and on the number of nodules was observed.

Nitrogen and to a lesser degree inoculation produced more kg N/m^2 than the control as the N % of the plant and the drymatter production was enhanced by both treatments. Applicating different levels of nitrogen could determine the optimum response of the legume (Parker and Chatel, 1982).

The differences found between the sites are related to the suboptimal conditions in some trials. An inadequate water supply (Table 4), and a lower soild fertility status (Table 3) at Meewatura, influenced the yield and dinitrogen fixation. A higher wee competition was also observed at Meewatura.

A low relationship between the nodule parameters and the drymatter production of plants was evident. Ikram and Broughton (1978) and Woomer *et al*. (1978) found the yield of winged bean to be best related to the N % and weight and number of nodules. As in this experiment the nitrogen content of the plants was increased by inoculation and NPK, it could be expected that the treatments would increase the seed yield as well. Inoculation reduced the total plant dry weight during the first two months with some strains, but an increase occurred after four months. Strain KUL-GP and even more KUL-JN increased the drymatter production more than N especially at Pallekele. The sampling stages were appropriate as Zulkifli and Othman (1977) reported that the highest effect of nodulation occurred between the 28th and the 56th day. Fewer, but bigger nodules were observed in the inoculated plots. Asanuma and Ayanaba (1982) found with cowpea a higher activity of inoculant strains suggesting a high symbiotic effectivity.

The host specificity between the selection SLS 44 and the strains KUL-JN and KUL-GP was significant. Iruthayathas (1984) found a low host specificity with other winged bean selections. KUL-GP and KUL-JN improved the vegetative production at both sites and KUL-GP also had the highest weight/plant.

The *Rhizobium* strains used were found to be highly effective in pot experiments (Iruthayathas, 1984). Similar results with selected strains were obtained by Zulkifli and Zakaria (1978), Ikram and Broughton (1979), and Woomer *et al.* (1978). However, in these experiments inoculation also could decrease the yield and the number of nodules under some conditions. This was confirmed by Vincent, 1982, and Obaton, 1983. This yield decrease after inoculation is usually explained as being the effect of the competition of the native strains (Subba Rao, 1976). The cowpea group bacteria are widely available in tropical soils. Elmes (1976) and Ikram and and Broughton (1979) found that in all tropical soils the promiscuous winged bean will nodulate to some extent. In these experiments, even the control performed well. Effective, native rhizobia were thus naturally present in sufficient numbers. As a consequence it can be concluded that at least an equal number of nodules should have been found in the inoculated plots, being the sum of the infection of the native and the introduced strains.

Trinick (1982) noted that some strains have the ability to decrease the number of possible infection sites. The mechanism is not clear yet. This inhibition could take place either after the infection of the strain, or before the infection, in the rhizoplane. As this characteristic improves the competitivity of these strains, a higher number of nodules with the said strain, resulting in a better yield could be expected. yet no significant yield increases were demonstrated in the experiments. If the strains tested have the prohibitory character and if no other factors were involved it could be that the strains have failed in effectiveness in the prevailing field conditions.

The inoculation process itself can be responsible for a lower competitive ability. Ikram and Broughton (1978) suggested that reinoculating several times, would increase the inoculant strain representation in the nodules, which was confirmed by De Coster (1980) who found increased nodulation with an increase of the inoculum rate and seed inoculation was found to be better than soil inoculation. Under extreme dry conditions, Ayanaba and Nangju (1974) found a granular inoculant to be better.

The incongruities found between the results obtained in the preliminary tests of the selected strains compared to the field trials, are partly explained by the following observations. Most initial trials were done under sterile conditions in pot experiments with complete mineral nutrition. In the field trials however, N was used as a control but the other elements were often not supplied. Future experiments will include inoculation with a mixture of the same strains and a complete fertilizer mixture, including micro nutrients.

The relatively low performance after inoculation in comparison with N could be improved according to Ayanaba and Nangju (1974). Tropical soils are deficient in N and do not allow sufficient initial root growth for good nodulation. They concluded that selected strains could perform better in the presence of N. Although Iruthayathas (1984) reported that most strains, used in this experiment, are tolerant to high N levels in the soil, an inhibitory, though not significant, effect of N on the nodule formation was evident in this study. However, KUL-GP was tolerant to high N levels. Similar inhibitory effects of N were found by Lie (1974), De Geus (1974) and many others. Therefore, care will be needed in isolating and selecting suitable *Rhizobium* strains.

As for other legumes, important research on the plant physiology of winged bean has to be done (Wery and Grignac, 1983). Changes in the translocation of photosynthates to the different sinks could allow to improve the yield. The availability of non-nodulating isolines, non-fixing *Rhizobium* strains and pure selections of winged beans could boost the research on dinitrogen fixation of winged bean. Further research should include the use of multistrain inoculants and a complete basal dressing, to overcome the site and selection variation.

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EFFECT OF FLOODING, DEPTH OF PLANTING AND SIZE OF CLUSTER ON GROWTH OF GREENGRAM AND BLACKGRAM SEEDLINGS.

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SUMMARY

A seedling experiment was conducted using greengram (Phaseolus aureus, cv 'MI-1') and blackgram (Phaseolus mungo, cv 'MI-1') to investigate effect of flooding, depth of planting and size of cluster (number of seeds per hill) on seedling emergence and growth as measured by plant height, shoot and root weights and root length. The treatment combinations comprised of factorial combinations of four flooding treatments; flooding for a constant period of 12 h at three different intervals after sowing and a control (no flooding), three depths of planting and three cluster sizes. The experiment was carried out for a period of three weeks. Analysis of variance was carried out for each cluster size separately. The 2 seed cluster had slightly lower CV values (around 35%) than 3 seed cluster, while single seed cluster had very high CV values (around 70%). There were no significant interaction between flooding treatments and depth of sowing for each clustering level. Flooding at 24 h after sowing resulted in no seedling emergence for green gram for 1 and 2 seed clusters while a negligible number of seeds emerged for 3 seed clusters. There were no significant differences among the other level of flooding. However, blackgram was affected when flooded at 12 h after sowing but survived flooding even at 24 h after sowing. Significant differences were not observed for different depths of sowing at any clustering level, for both crops except in the case of root length, which gave significantly higher values at the highest depth (6 cm) of planting. In general the SE(d) for each growth parameter was much higher for 1 seed cluster when compared to 2 or 3 seed clusters.

INTRODUCTION

Flooding an air dry soil leads to a series of changes in physical, chemical and biological processes that influence the quality of a soil as a medium for plant growth. Excess water causes injury in terrestrial plants due to development of anaerobic conditions (Cannell, 1979). Flooding experiments conducted on crops such as cowpea (Wien et al. 1979), corn (Purvis and Williamson, 1972) and alfalfa (Thompson and Fick, 1981) have shown that flooding reduced germination and emergence of seedling, decreased root weight and led to rotting of tap roots. These adverse effects increased in intensity, with higher periods of flooding. Flooded conditions could be a general problem in the Mahaweli area.

With the development of large tracts of lands for cropping in the Mahaweli areas, the emphasis has shifted from the cultivation of rice to the growing of other crops such as pulses and chillies, in the Yala season. However, such lands can get flooded during rains which occur over short periods.

Studies conducted on the depth of planting on growth of soybean (Singh et al. 1971 and Stitt, 1948) have shown that seedling emergence was reduced when planted at depths higher than 6 cm.

According to Mayer and Poljakoff-Mayber (1982) in some cases a single seed is unable to pierce the surface seal and emerge. Brar et al (1982) reported that emergence significantly increased with an increase in the number of seeds (cluster size), up to 5 seeds per hill.

In this study the effect of flooding, depth of planting and size of cluster on greengram and blackgram which are traditionally important in the Dry Zone of Sri Lanka were investigated. These are cultivated as rainfed crops in the wet season (Oct. - Jan.), and in rice fields as catch crops in Yala (May - Aug.) either under rainfed or irrigated conditions.

The depth of planting and cluster size are included in the experiment to determine whether these factors could be used to compensate for the adverse effects of flooding during the most critical time i.e. soon after sowing.

MATERIALS AND METHODS

Pot experiments were conducted in the greenhouse on greengram (Phaseolous aureus, cv 'MI-1') and blackgram (Phaseolus mungo, cv 'MI-1') at the Peradeniya University using reddish brown latasolic soils in both trials.

The flooding treatments included a control(No flooding, FO) and flooding at 3 different intervals after sowing i.e. F_1 (immediately after sowing) F_2 (12 h after sowing) and F_3 (24 h after sowing). In each case the soil was kept in the flooded state for 12 h. Three depths of planting were used : 2 cm, 4 cm and 6 cm. In addition 3 cluster sizes were also used : 1 seed, 2 seed and 3 seed clusters. A factorial randomized complete block design with 3 replicates was used.

The seedlings were raised in cylindrical plastic pots, 16 cm deep and 15 cm diameter, having drain holes at the bottom. Pots were lined with polythene and each pot was filled with 3 kg of air - dried soil which was passed through a 2 mm sieve and compressed to obtain a bulk density of 1.2 Mg/m^3.

Water was added to each pot at 24 h prior to planting until a moisture content of 20% by weight was reached. Twelve hours after the flooding treatments were applied, the bottom of each polythene bag was punctured through the drain holes of each plastic pot and the water was allowed to drain freely.

Throughout the period of the experiment (0 - 3 Weeks after planting) except during the flooded stage, soil moisture was maintained at 20% by weight.

The growth parameters measured were rate of seedling emergence, main stem length from surface of soil to tip of the terminal bud (at the end of 20 days from planting), shoot and root dry weights and root lengths of seedlings harvested at 20 days from planting. All samples were oven dried at 60 ^{o}C before recording dry weights.

RESULTS AND DISCUSSION

Seedling emergence was drastically reduced when subjected to flooding 24 h after sowing. In greengram, % emergence was zero at all cluster sizes except size 3, while for blackgram at all cluster sizes seedlings emerged at 24 h flooding, only when planted at the higher depth of 6 cm and that too only after 7-8 days (Fig. I). This shows that at a higher planting depth blackgram seedlings are able to survive the flood and emerge later. When pots were not flooded seedlings emerged around the third day, while at 12 h flooding emergence was around the sixth day in both crops.

Preliminary analysis showed that all interactions were non-significant. However, the coefficient of variability (CV) was found to be very high (65%). Separate analysis by cluster size showed that CV for cluster size 2 (35%) was slightly lower than for cluster size 3, while CV for cluster size 1 was very high (70%).

Due to the heterogeneity of variance for different cluster sizes, the analysis was carried out separately by cluster size.

The interaction effect was non-significant at every cluster size and for both crops. Significant differences were observed only with respect to flooding factor for plant height, shoot and root dry weight. However, both main effects were significant with respect to root length in both crops for cluster sizes 2 and 3. For cluster size 1 main effect of depth of planting was non-significant in both crops.

Table I gives the mean plant height for different flooding levels at each cluster size for each crop. For greengram no plant emerged at 24 h flooding for cluster sizes 1 and 2. However, there were no significant differences among the other 3 levels of flooding except for cluster size 1, where 12 h flooding depressed plant height.

Due to seedling emergence at 24 h flooding blackgram recorded a low value at 6 cm depth (no emergence at other depths). There were no significant differences among other levels of flooding for each cluster size. The trend in both

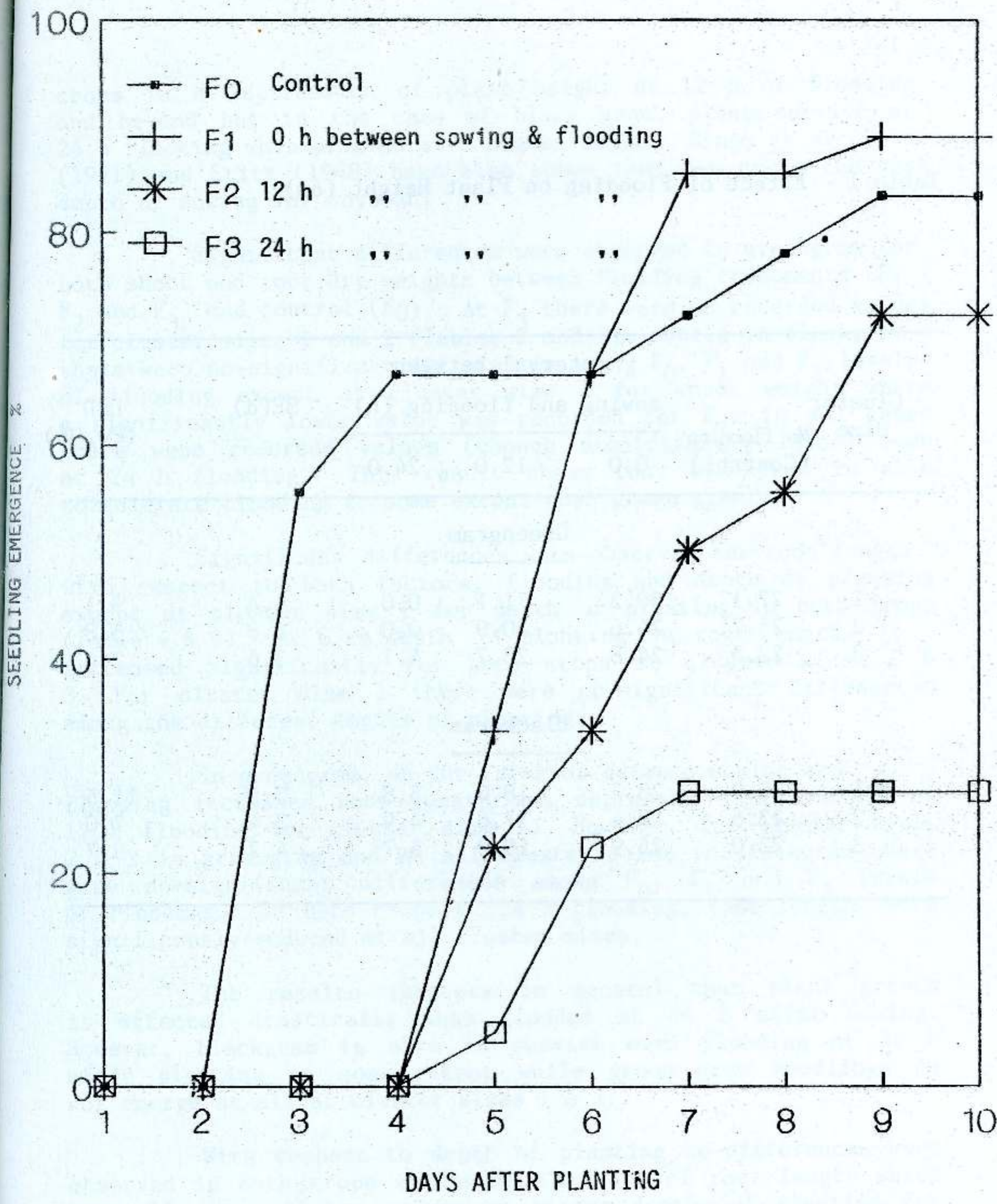

Fig. 1 Seedling emergence of blackgram at 6 cm dept. as affected by various flooding treatments

Table 1 Effect of Flooding on Plant Height (cm)

Cluster size	No flooding (Control)	Interval between sowing and flooding (h) 0.0	12.0	24.0	SE(d)	LSD (P=.05)
			Greengram			
1	27.1	30.3	11.1	0.0	4.4	9.1
2	25.7	24.6	20.9	0.0	2.8	5.8
3	22.5	24.8	23.7	4.1	3.6	7.4
			Blackgram			
1	25.2	23.2	18.0	5.8	5.5	11.5
2	23.6	29.4	17.6	4.9	3.4	7.0
3	23.0	25.9	19.9	5.7	4.7	9.7

crops is a suppression of plant height at 12 h of flooding and beyond but in the case of black gram, plants survive at 24 h flooding when planted at a higher depth. Singh et al (1971) and Stitt (1948) have also shown that 5-6 cm is the best depth of sowing for soybean.

Significant differences were observed in greengram for both shoot and root dry weights between flooding treatments (F_1 F_2 and F_3) and control (F_0). At F_3 there were no recorded values for cluster sizes 1 and 2 (Tables 2 and 3). While in blackgram there were no-significant differences among F_0, F_1 and F_2 levels of flooding except at cluster size 1 for shoot weight where a significantly lower value was recorded for F_2. In all cases there were recorded values (though significantly lower) even at 24 h flooding. This result shows that blackgram is able to tolerate flooding to some extent than green gram.

Significant differences were observed for root length with respect to both factors, flooding and depth of planting except at cluster size 1 for depth of planting in both crops (Table 4 & 5). At 6 cm depth of planting the root length increased significantly for both crops at cluster sizes 2 & 3. For cluster size 1 there were no-significant differences among the different depths of planting.

In greengram, as the interval between sowing and flooding increased root length was depressed significantly at 12 h flooding for cluster size 1. However, for cluster sizes 2 & 3 in greengram and at all cluster sizes in blackgram there were no-significant differences among F_0, F_1 and F_2 levels of flooding. In both crops at 24 h flooding, root length were significantly reduced at all cluster sizes.

The results indicate in general that plant growth is affected drastically when flooded at 24 h after sowing. However, blackgram is able to survive even flooding at 24 h after planting to some extent while green gram seedlings do not emerge at all at cluster sizes 1 & 2.

With respect to depth of planting no-differences were observed in both crops except in the case of root length which generally gave higher values at higher depths of planting for both crops.

Table 2 Effect of Flooding on Shoot Weight (mg/plant)

Cluster size	No flooding (Control)	Interval between Sowing and flooding (h)			SE(d)	LSD (P=.05)
		0.0	12.0	24.0		
		Greengram				
1	189.1	114.7	67.9	0.0	26.7	55.4
2	171.0	106.4	118.1	0.0	22.5	46.7
3	136.5	83.3	127.1	14.8	15.7	32.6
		Blackgram				
1	206.7	119.3	97.3	40.6	35.6	73.8
2	179.6	110.8	135.2	49.1	35.4	73.4
3	183.0	107.6	127.9	35.2	35.6	73.8

Table 3 Effect of Flooding on Root Weight (mg/plant)

Cluster size	No flooding (Control)	Interval between sowing and flooding (h) 0.0	12.0	24.0	SE(d)	LSD (P=.05)
		Greengram				
1	35.3	25.0	16.2	0.0	5.9	12.1
2	37.8	21.3	23.7	0.0	5.1	10.5
3	35.3	17.3	19.4	3.3	4.2	8.8
		Blackgram				
1	38.8	25.0	26.3	7.2	8.1	16.7
2	29.9	22.2	21.2	7.8	5.7	11.9
3	32.0	21.9	22.6	5.3	5.8	12.0

Table 4 Effect of Flooding on Root Length (cm)

Cluster size	No flooding	Interval between Sowing and flooding (h)			SE(d)	LSD (P=.05)
		0.0	12.0	24.0		
			Greengram			
1	4.5	5.4	2.1	0.0	0.9	1.8
2	4.6	5.5	4.7	0.0	0.7	1.5
3	4.7	5.0	4.6	1.0	0.8	1.6
			Blackgram			
1	4.0	3.8	4.2	1.2	1.1	2.3
2	4.5	4.9	4.8	1.6	0.8	1.6
3	4.1	3.8	5.1	1.2	0.9	1.9

Table 5 Effect of Depth of Planting on Root Length (cm)

Cluster size	Depth 2 cm	4 cm	6 cm	SE(d)	LSD (P=.05)
		Greengram			
1	2.6	3.3	3.5	0.8	1.6
2	3.2	3.0	4.9	0.6	1.3
3	3.1	3.5	4.8	0.7	1.4
		Blackgram			
1	2.9	3.1	3.9	0.8	1.6
2	3.1	3.0	5.7	0.8	1.6
3	2.5	3.0	5.1	0.8	1.6

Cluster sizes of 2 & 3 showed much less variability than cluster size 1. The standard errors were in some cases more than twice for cluster size 1 when compared to cluster sizes 2 & 3 . It should be noted that in the present experiment there was no indication of crust formation, in which case cluster size of 3 should have given higher seedling emergent percentages.

Controlled field experiments are necessary as a follow up of these greenhouse trials before conclusions are made. However, this study suggests that for lands which are subject to rather infrequent floods of short duration, seeding more than 1 seed per hill at a higher depth can lead to better seedling establishment.

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PROPAGATION OF STEM CUTTINGS OF POTATO (*SOLANUM TUBEROSUM*)

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ABSTRACT

The cultivation of potato in most developing countries is hampered by the lack of sufficient good quality seed potatoes for crop establishment at required times. The stem cutting technique is considered a good alternative to overcome problems associated with the lack of planting material. Thus a study was carried out with stem cuttings of two physiological ages (simple and compound leaf) from in vitro mother plants of potato to determine their rooting ability in different potting media, with and without a rooting hormone (N A A). The potting media used were made up of gravel, river sand, organic matter (cowdung) and burnt paddy husk and black peaty soil, mixed in different proportions. Simple leaf cuttings planted in gravel showed maximum rooting when compared with other media. Rooting was poor in the heavy textured media with organic matter and peaty soils. Rooting hormone increased the number and vigour of roots. In contrast, shoot growth was optimal in the heavy media which contained a greater quantity of organic matter. Simple leaf cuttings showed rapid and vigourous growth of both shoots and roots when compared with compound leaf cuttings.

INTRODUCTION

The potato is the most important root crop in the world, ranking fourth among all crops. Thus, it is cultivated in a wide range of ecological conditions, in the temperate and tropical world, in both developed and developing countries (Plucknett, 1984). While the crop is considered a basic dietary component in the developed world, it is a luxury vegetable in most developing countries, especially in humid tropical Asia (Van der Zaag and Horton, 1983). It's production is oriented around large farms in the developed world. The farmers of the developing world tend to favour the cultivation of this crop in small farms, if the environmental conditions are favourable, due to the high prices fetched by the commodity. Thus, there is an expansion of cultivation of potato, especially in the developing world.

Current potato production of approximately 112000 MT in Sri Lanka is from 7700 Ha (Ministry of Agriculture, 1987). The extent cultivated with potato has increased by 9.9% in the decade 1975-85 (FAO, 1986). Most cultivations of potato in Sri Lanka are situated in the wet zone of the island, as smallholdings.

All farmers of potato depend heavily on the supply of seed material for crop establishment. The current seed requirement is approximately 4210 MT of seed tubers (Ministry of Agriculture, 1987). As in most developing countries (Horton et. al, 1984), seed tubers are very expensive in Sri Lanka. In addition, the lack of good quality seed material at required times in required quantities has been a setback to potato production in Sri Lanka (Rhodes, 1982). Thus, research is now being carried out to produce true potato seed and evaluate other methods of developing planting material.

Due to the problems of seed tuber production and availability, the International Potato Centre is currently conducting research on different methods of potato propagation in order to improve the seed technology component that is suitable for the development of a self sustaining potato production system in the developing world (CIP, 1987). The techniques evaluated are establishment of tubers, transplanted rooted cuttings and transplanted true potato seed. In addition techniques of tissue culture are being evaluated.

Farmers in Sri Lanka have traditionally used seed tubers, and continue to do so (Rhodes, 1982). Due to the problems of seed tubers, research has begun on other types of propagating material. As rooted cuttings have proven to be beneficial at CIP, and due to its low cost and non use of a marketable product, a study was carried out to evaluate techniques of propagating cuttings under Sri Lankan conditions. Emphasis was placed on evaluating the growth of cuttings from selected mother plants, when established in potting media developed from locally available low cost material.

MATERIALS AND METHODS

The study was carried out at the Potato Research Centre of Tobacco Company Ltd., situated in the heart of the potato growing region of Sri Lanka, at Nuwara Eliya (1900 M above sea level). The experiment was conducted in a plant house having the mean environmental conditions of 20.6° C temperature, 70.6% relative humidity and a 12 hour daylength, provided by artificial light. The plant house was covered with nylon mesh to intercept 50% of the incident radiation.

The material selected to develop the potting media were coarse gravel (2 - 5 mm), peaty black soil, decomposed cattle manure (cattle dung), river sand (0.5 - 1 mm) and half burnt paddy husk. The media developed were GRAVEL, MIXTURE OF COWDUNG AND TOPSOIL (1:1 ratio), RIVER SAND and a 1:1:1 ratio MIXTURE OF PADDY HUSK, RIVER SAND and BLACK SOIL.

The types of cuttings obtained from selected mother plants of variety 'Desiree', were namely simple leaf and compound leaf cuttings. Simple leaf cuttings were 4 - 5 cm long, with two well developed and two unexpanded simple leaves and having a mean dry weight of 0.012 ± 0.004 g. The compound leaf cuttings were 6 - 7 cm long, with two well expanded and two unexpanded compound leaves. The mean dry weight of these cuttings was 0.036 ± 0.009 g. These were established in the different potting media with or without a rooting hormone, Napthelene Acetic Acid. Thus 16 treatments were developed in a randomized block design with four replicates.

The potting media were steam sterilized and filled into disinfected small plastic pots of dimensions 4 X4X4 cm, and placed on a wire mesh 1 meter above ground level. The cuttings were established in the pots soon after incision from mother plants. The cut ends of planting material were dipped in the rooting hormone and planted.

A foliar fertilizer of 15:30:15 N.P.K was sprayed at 5 day intervals. Irrigation was provided at regular intervals and routine applications of fungicides and pesticides were carried out.

Cuttings were examined daily upto 8 days to determine root initiation. In addition, cuttings were sampled at the 10th and 20th day after establishment to determine total root length (Tennant, 1975), number of productive leaves per plant and total dry matter, by drying plants at $80^{o}C$ for 48 hours.

RESULTS AND DISCUSSION

The daily samples clearly indicated the beneficial effect of rooting hormones in initiating roots of potato cuttings. All treated were seen to initiate roots earlier. In addition, simple leaf cuttings developed roots earlier than compound leaf cuttings. This phenomenon can be attributed to the more succulent nature of simple leaf cuttings when compared to compound leaf cuttings.

The trend in root initiation of both simple and compound leaf cuttings did not vary with the type of potting medium. Simple leaf cuttings established in gravel and river sand developed roots in 2 - 3 days, while compound leaf cuttings developed roots in 3 - 4 days in this medium. Root initiation of simple leaf cuttings in the other two heavy textured media was observed in 5 - 6 days. Compound leaf cuttings indicated root development in 7 - 8 days in these media. Thus loose textured media can be considered suitable material for root initiation of potato cuttings. The root development of the different types of cuttings with and without hormones and planted in different media are presented in Table 1. Again, the benefits of using a rooting hormone is clearly seen. The increased root growth of cuttings treated with the hormone can be attributed to earlier and better root development induced by the chemical. Simple leaf cuttings show better root development in all media when compared to compound leaf cuttings, suggesting the importance of the physiological age of the cuttings in enhancing root development.

The effect of potting media on root length follows the pattern of root initiation, primarily due to the close relationship between root initiation and development (Bohm, 1979). The loose textured gravel produces 180 cm of roots in 20 days in simple leaf cuttings treated with hormones. Poor rooting development was observed in the heavier textured media (Cowdung + Black soil; Paddy husk + River sand + Black soil). Greater microbial activity due to organic matter and greater water holding capacity of these media may be considered as causal factors to this observation.

A comparison of the two heavy textured media show better root growth of simple leaf cuttings in the medium with river sand. This could be attributed to beneficial effects of adding sand to improve the texture. However, the contrast is seen in compound leaf cuttings. Thus, if heavy textured media are used, the data suggests the benefits of adding river sand, especially for simple leaf cuttings. Compound leaf cuttings may prefer a heavier medium.

The effects of hormones and potting media in leaf production of simple and compound leaf cuttings are not well defined (Table 2). However, the data indicates a trend of greater leaf numbers in compound leaf cuttings planted without hormones, with the exception of the sand medium, on the 20th day. The magnitude of differences between treated and untreated compound leaf cuttings is greater in plants established in the heavy textured media, which shows poor root development (Table 1). This suggests that while light textured media induce rooting, the heavier textured media promote better leaf development, especially in the absence of a rooting hormone. The results also indicate an inverse relationship between root growth and leaf development of potato propagules at this stage.

The effect of the adopted treatments on plant growth (determined on the basis of dry weights) are presented in Table 3. The greater dry weights of the compound leaf cuttings can be attributed to the greater initial weights of the cuttings. The treatment effects are not clearly highlighted in the first harvest. However, the dry weights of simple leaf cuttings established in sand are significantly greater. Similarly compound leaf cuttings show greater dry weights when planted in gravel. This again suggests the value of light textured media in producing good planting material of potato.

The above trend is again observed at the 20th day. The highest dry weights are seen in cuttings planted in sand, when subjected to hormonal treatment. This is followed by dry weights of treated cuttings in gravel. This increase in dry weights of cuttings treated with hormones can be attributed to better and more prolific root development induced by the chemical. The comparison of dry weights of cuttings in the heavier textured media also indicate better growth in the medium with sand, which can be considered to have a lighter texture than the Cowdung: Black soil medium. This clearly illustrates the benefits of light textured media in producing good planting material of potato.

The greater plant weights observed in compound leaf cuttings are similar to that observed in simple cuttings. This confirms the value of lighter textured media, especially with a hormone for the production of good planting material from potato cuttings of different physiological ages. A primary objective of a rapid propagation programme is to develop healthy propagules of potato with well developed root systems for field planting (Van der Zaag and Graza, 1983). This study proves the ability of developing good propagating material with stem cuttings, which develop good root systems. Simple leaf cuttings produce better planting material than compound leaf cuttings, confirming earlier reports of Nelson Melendez et al (1981). However, compound leaf cuttings could also be used for developing planting material, although growth may be slower.

The importance of using a rooting hormone is shown in this study. As a major objecive of a programme of developing suitable propagating material is to obtain a good root system, the use of a hormone, although expensive, is important in a high value crop such as potato. The value of a light textured well aerated potting medium with a lower water holding capacity is shown in the study. Thus, as reported by Bryan et. al (1981), this experiment shows the value of sand or gravel to establish cuttings, under a good foliar fertilizer programme to produce good propagating material. The success of such a programme is enhanced if simple leaf cuttings are used. However, in times of short supply of simple leaf cuttings, compound leaf cuttings can be used.

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Table 1. Effect of Potting Media and Hormones on Root Length (cm) of Propagules.

TREATMENTS		DAYS AFTER PLANTING	
Potting Media	Hormonal Treatment	10	20
A. SIMPLE LEAF CUTTINGS		(cm)	
Gravel	+ Hormone	19.03	180.39
	- Hormone	5.57	140.50
Cowdung + Black soil	+ Hormone	4.15	78.69
	- Hormone	2.45	56.44
River sand	+ Hormone	10.95	137.63
	- Hormone	7.90	99.65
Paddy husk, + River sand + Black soil	+ Hormone	6.75	156.61
	- Hormone	1.20	43.34
L S D (P=0.05)		1.77	4.84
B. COMPOUND LEAF CUTTINGS			
Gravel	+ Hormone	12.28	148.49
	- Hormone	1.77	88.09
Cowdung + Black soil	+ Hormone	1.08	65.99
	- Hormone	-	33.91
River sand	+ Hormone	4.91	117.95
	- Hormone	4.07	80.88
Paddy husk + River sand + Black soil	+ Hormone	1.18	43.21
	- Hormone	1.04	11.78
L S D (P=0.05)		7.88	11.75

Table 2. Relationship between Potting Media, Hormones and Leaf Number of Potato Propagules.

TREATMENTS		DAYS AFTER PLANTING	
Potting Media	Hormonal Treatment	10	20
A. SIMPLE LEAF CUTTINGS		New leaves/plant	
Gravel	+ Hormone	2.16	3.44
	− Hormone	2.33	3.35
Cowdung + Black soil	+ Hormone	1.83	4.50
	− Hormone	1.66	3.83
River sand	+ Hormone	2.10	3.18
	− Hormone	2.16	3.42
Paddy husk, + River sand + Black soil	+ Hormone	1.83	3.31
	− Hormone	1.82	3.50
L S D (P=0.05)		0.14	1.21
B COMPOUND LEAF CUTTINGS			
Gravel	+ Hormone	1.83	3.35
	− Hormone	2.66	3.50
Cowdung + Black soil	+ Hormone	1.84	3.66
	− Hormone	2.00	3.83
River sand	+ Hormone	1.83	3.50
	− Hormone	2.67	3.33
Paddy Husk + Black soil	+ Hormone	1.67	3.16
L S D (P=0.05)		0.23	0.72

Table 3. Effect of Potting Media and Hormones on Dry Weight Propagules.

TREATMENTS		DAYS AFTER PLANTING	
POTTING MEDIA	HORMONE TREATMENT	10	20
A. SIMPLE LEAF CUTTINGS		g/plant	
Gravel	+ Hormone	0.031	0.067
	- Hormone	0.044	0.058
Cowdung + Black soil	+ Hormone	0.032	0.059
	- Hormone	0.030	0.051
River sand	+ Hormone	0.051	0.088
	- Hormone	0.048	0.074
Paddy husk, + River sand + Black soil	+ Hormone	0.021	0.061
	- Hormone	0.024	0.58
L S D (P=0.05)		0.002	0.005
B COMPOUND LEAF CUTTINGS			
Gravel	+ Hormone	0.064	0.088
	- Hormone	0.059	0.074
Cowdung + Black soil	+ Hormone	0.051	0.064
	- Hormone	0.052	0.061
River sand	+ Hormone	0.059	0.104
	- Hormone	0.055	0.092
Paddy husk + River sand + Black soil	+ Hormone	0.048	0.079
	- Hormone	0.043	0.068
L S D (P=0.05)		0.004	0.003

EXTENSION COVERAGE IN THE T&V SYSTEM : SRI LANKAN EXPERIENCE

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SUMMARY

During the past decades, agricultural extension has gained ground in development programmes. As one of the development policy instruments available, extension strategies have made various efforts to reach small farmers. However, it is evident that in many instances, extension programmes followed the line of conventional diffusion model, limiting the benefits to a small number of farmers. Such extension programmes have contributed to an increase in disparities among farmers as the extension coverage was imbalanced to a great extent. Hence, agricultural extension, so promising of improving the productivity by disseminating scientific knowledge, has made a marginal impact on subsistence farmers in the developing countries. The above realization warranted new or modified extension approaches which focus on small producers. The Training and Visit (T&V) System of Agricultural Extension is a such an effort. With its systematic, time-bound extension schedule, the system makes a great deal to expand extension coverage. However, empirical studies are limited to understand how the system actually works in the field. In fact, T&V system is in its infant stages of implementation, therefore, its reliance has to come yet. Based on an investigation carried out in Sri Lanka, this paper attempts to examine the differences in formal and actual situations with respect to extension coverage. The results demonstrate that farmers still regard extension agent as their main source of agricultural knowledge and the Contact Farmers (CFs) have not well penetrated into extension framework as 'catalizers'. Therefore, the 'two-step-flow' of information does not work

effectively as previously conceived. Further, imperfections exist in frequency and regularity of Village Extension Workers' (VEWs) visits. Therefore, relevant modifications are needed in order to bring reasonable return to the investment.

INTRODUCTION

The Training and Visit (T&V) System of Agricultural Extension (Benor and Harrison, 1977, Benor et al, 1984) has been deliberately introduced to many of the developing countries since mid-seventies to deal with cruel bottlenecks found in extension systems. The bottlenecks were often, lack of systematic extension programme planning, staff shortages, training difficulties, low performance of extension personnel due to lack of technical up-dating, duties in addition to advisory work, high ratio of Farmers/Extension Agent, weak research - extension - farmer linkages and lack of co-ordination. The T&V system is regarded as a hierarchically organized time-bound extension management system. Its philosophy has been extensively elucidated elsewhere, I shall not go into a detailed description of the system but is worthwhile to mention that the system makes a great effort to reach a wider clientele through the contact farmer approach. In other words, with frequent and regular visits to farmers by extension workers, the system attempts to extend the extension coverage. The extension coverage refers to the extent to which farmers in a category or social system are regularly and frequently served by the extension organization and benefit from that service (Wijeratne, 1988). This definition seems quite reasonable in evaluating extension coverage of the T&V system as regular and frequent visits by the extension agents to their clients are a key feature of this approach. Therefore, frequency and regularity of VEW's visits are considered as important indicators in the investigation.

This system was first tried in Turkey in late sixties and it is evident that many developing countries are inclined to adopt it as they felt the need of extension re-orientation. Further, in most instances, the system has received a sound financial assistance from the World Bank for its implementation. In fact, this reason has made a significant impact on T&V's popularity among the developing countries. Sri Lanka is in the pioneering group which adopted the system. First, it was introduced to a dry-zone district as a pilot project in 1976 and subsequently implemented in all the other districts from Maha season 1979/80 (Ranaweera and Silva, 1982, Department of Agriculture, 1985). One of the main problems in virtually all extension services in the traditional sense is that they have to serve a large number of scattered small production units with a handful of trained manpower. This, often has led to have intense contact with a small number of farmers and no contact whatsoever with the vast majority. In Sri Lanka, such problem was existed in the former extension set-up and was recognized. The T&V system was adopted partly to overcome this adverse situation.

One of the main objectives of the T&V system is to expand the extension coverage (Feder et al, 1985a, Blum and Isaac, 1988). Essentially, it should be, because this was one of the notorious limitations found in many extension organizations. The system emphasizes frequent and regular extension contacts to CFs but the VEW are expected to respond to all the farmers who approach him with queries (Benor and Baxter, 1984). An Indian study has discovered that for CFs, not seeing the extension agent ranges from 1.2% to 34.7% while for Follower Farmers (FFs) it ranges from 21.4% to 59.2% for the same reference period (Feder et al, 1985b). The same study has investigated the trends in extension contacts in relation to T&V experience. The results show that, percentage of CFs not visited increases significantly as project age progresses but in contrast, FFs 'no visits' has declined (Feder et al, 1985b). The frequency and regularity of extension agent's visits were also examined by the same researchers. The results imply that 80% of the CFs and 20%- 25% of the FFs have received at least one visit per month. Moreover, 30% of the CFs and 73% of the FFs, who had visits in the reference period, have reported irregularity in visit schedule. A recent study demonstrates that 'zero visit' rate for CFs tends to remain constant around 20% while the same for FFs has declined as the system experience increases (Slade et al, 1988). This achievement can be regarded as a better performance but it is far below the expectation of the T&V re-orientation.

In the T&V notion, CFs are supposed to establish a strong link between the extension service and the farming community. Further, they are expected to act as local catalysts. According to the Sri Lankan T&V model,CFs represent 10% of the farmers and each CF is given a group of FFs. Generally, this group consists of 21-25 members. The CFs', essentially have to understand their role as their effective co-operation has a significant impact on the success of this approach. The interaction between CFs and FFs is also an indicator which can be utilized to evaluate extension coverage. A study reveals that about 40% of the FFs were not acquainted with VEW even after six years of T&V experience (Slade et al, 1988). Another investigation demonstrates that, on average, 20%-30% of the CFs have not interacted with VEWs and therefore, they cannot be considered as communicators of extension messages to the FFs (Hoeper, 1988). A research carried out in Phillippines has experienced that 26% of the FFs were unable to name their respective CFs (Nagel et al, 1983). A number of Sri Lankan studies too, provide valuable information to the T&V knowledge pool. It has been demonstrated that extension messages were insufficiently communicated to the clients as approximately three-fourth of the farmers stated that only upto 50% of the CFs really co-operate in the dissemination of messages to the FFs. (Sivayoganathan, 1980). Another study of the same author (1985) reports that approximately 63% of the FFs have got information from VEWs and that only 11% of the FFs have ranked CFs as the first source of information. Gunawardena and Chandrasiri (1981) have stated that CFs were not fully conversant with their role and further, the other farmers were still dependent on the VEWs. Another study implies that 38% of the FFs are not aware of their respective CFs (Hindori and Renselaar, 1982).

METHOD

This study has been carried out in one of the wet-zone districts in southern Sri Lanka --- Matara. The average rainfall ranges from 2500 mm per annum in the coast to more than 5000 mm per annum in the mountain upper catchment areas of the district. Average temperature is around 30°C and the relative humidity is constant throughout the year, approximates 75%. Red-yellow podzolic soils occupy the major part of the district. The district consists of three agro-ecological zones, namely, coastal, central and northern. The extension orientation corresponds to the agro-ecological zones as hierarchical framework of the T&V system operates on the basis of three segments (as southern, central and northern). As this study concentrates on rice culture, central agro-ecological zone was considered. Comparatively, this zone has an even distribution of rice small holdings over its territory. Using the farmers' lists available at the Agricultural Services Centers, 50 CFs and 50 FFs were randomly drawn. The field investigation was done during 1986-87 and a pre-tested questionnaire was employed for data gathering. Indepth interviews were carried out with extension officers such as Agricultural Officers (AOs), Subject Matter Officers (SMOs), Agricultural Instructors (AIs) and VEWs. Moreover, a series of exploratory studies were undertaken prior to the quantitative data collection. The findings of such studies revealed that albeit the Cultivation Officers (Cos) do not belong to the T&V structure, some farmers regard them as an information source. Therefore, their impact was also examined. Later, data processing and relevant statistical analysis have been done using the SPSS programme.

RESULTS

Farmers' main extension contact has been investigated. The formal links established by the T&V model are the AIs, the VEWs, and the CFs. Furthermore, COs are also regarded as an extension contact point since they too, are confined to village level. In fact, they render ancillary services.

Table 1 presents the results of cross-tabulation between type of extension contact and farmer type.

Table 1 demonstrates that in total, 9% of the farmers do not have any extension contact. It seems that they belong to a category of part-time farmers. Only 7% of the farmers keep contact with AIs whereas 64% of them do so with VEWs. Main reason for this difference is that VEWs were given a visit schedule to follow but even though AIs are field officers, they do mostly supervision and management of extension programme. Hence, they have little opportunity in reaching farmers. The CFs are not regarded as main extension contact by FFs. Hence, 'two-step-flow' of information has contributed insufficiently to extend the extension coverage to a wider clientele. In fact, this aspect needs a thorough treatment as it implies that the formal linkages, VEW - CF - FF, are not effective as previously conceived. Moreover, CFs' function as catalizers to the farming community is far below the expectation. Some farmers (19%) regard COs as their extension contact. The COs' duties generally fall outside the context of the dissemination of technical know-how but as they are also confined to the village level, some farmers tend to seek technical advice from them, too. As the COs often keep contacts among farmers, it is worthwhile to up-lift their agricultural knowledge by providing an appropriate training. In all, majority of the farmers, including the FFs still consider VEWs as the extension contact point and CFs have not taken up the 'burden' to 'trickle-down' extension recommendations. The T&V notion rests great confidence on the role performance of the CFs as a team of intermediaries but the above findings show that, still this situation has not realized in the Sri Lankan model.

As mentioned earlier, frequency and regularity of extension agents visits are considered as crucial indicators which reflect on extension coverage. Therefore, an attempt has been made to analyse the extension coverage using these indicators. The VEW' visit frequencies were classified into five classes, namely 'zero visits', visit paid, once in three months, once in two months, once a month and once in two weeks. In fact, the last class corresponds to the visit frequency expected by the T&V approach. The first class, 'zero visits'

Table 1. Association Between Type of Extension Contact and Farmer Type

Count Row % Column %	Formal Farmer Type Contact Farmers	 Follower Farmers	Total
Type of extension contact			
No contact	2 22% 4%	7 78% 14%	9 100% 9%
AIs	5 71% 10%	2 29% 4%	7 100% 7%
VEWs	34 53% 68%	30 47% 60%	64 100% 64%
COs	9 47% 18%	10 53% 20%	19 100% 19%
CFs	0 0% 0%	1 100% 2%	1 100% 1%
Total	50	50	100

Statistics		Value	Significance
Kendall's Tau	(C)	-0.00720	0.4711

Table 2 : Relationship between VEW's Visit Frequency and Farmer Type.

Count Row % Column %	Formal farmer type		Total
	Contact Farmer	Follower Farmer	
VEW's visits frequency			
zero visits	8 40% 16%	12 60% 24%	20 100% 20%
Once in 3 months	6 38% 12%	10 62% 20%	16 100% 16%
Once in 2 months	15 71% 30%	6 29% 12%	21 100% 21%
Once a month	13 50% 26%	13 50% 26%	26 100% 26%
Once in 2 weeks	8 47% 16%	9 53% 18%	17 100% 17%
Total	50	50	100

Satistic	Value	Significance
Kendall's Tau (C)	-0.07000	0.2687

means that the farmer has not received a visit during the entire cultivation season which approximates to a spell of four months. Table 2 illustrates the result of the cross-tabulation of VEW's visit frequency and farmer type.

Table 2 demonstrates that 20% of all farmers have reported 'zero visits'. Even 16% of the CFs were not visited. Next, 72% of the CFs have received at least a visit in two months while only 56% of the FFs were visited with this intensity. This shows that there is a difference in VEW's visit frequency for the two farmer types. This can be expected as the system emphasizes intense contacts to the CFs. However, in total, only 17% of the farmers were visited according to the T&V notion. Moreover, only 16% of the CFs have received fortnightly visits but the FFs have reported a slightly higher percentage (18%) for this intensity. It seems that extension agents have a tendency to deal with 'interested ones' irrespective of formal farmer type. Further, VEWs are inclined to focus their concentration on the informal relationships established by themselves, probably prior to the T&V reform. In all, number of CFs who have received the recommended visit frequency is well below the standard of T&V. However, irrespective of farmer type, approximately, 40% of the farmers have received at least a visit per month. This can be viewed as a better performance over the outcome of previous situation, but one cannot satisfy with this achievement, as the contribution towards the improvement of extension coverage seems marginal.

Regularity of extension visits was investigated among the farmers who received at least a visit in three months. According to the Sri Lankan T&V model, a VEW has to contact six CFs per day and there are six visit days in his fortnightly programme. It seems that visits are often irregular. In fact, 60% of the farmers stated this condition. No significant difference has been observed between the two farmer types with respect to visit irregularity. The farmers as well as the extension agents have experienced some difficulties in following the time-bound visit schedule. With limited facilities given to the VEWs, the strict schedule has become inappropriate. Next, VEWs have to devote their time and energy to solve their day-to-day problems. Farmers too, are explored to the same situation. Finally, supervision of VEW's work has received little attention and further, there is hardly any provision for a reward system to reinforce VEWs' status in the social system.

CONCLUSIONS

Findings of this study reveal that, with respect to extension coverage, some differences exist between actual outcome of the T&V implementation over the expected situation. Most of the farmers still consider VEW as the main source of agricultural knowledge. It seems that the 'two-step-flow' of communication expected via VEW - CF - FF linkages has a marginal impact on the expansion of extension coverage. In fact, the CF's 'catalysing' function has not materialized and many of the CFs are aloof of their role and responsibilities. The frequency and regularity of VEW's visits show imperfections over the notion of T&V. The time-bound, strict visit schedule is impossible to maintain in the field condition. Only 16% of the CFs have received fortnightly extension contacts. The evidence shows that VEWs were given a task without much concern of the facilities available to them. However, approximately 40% of the farmers have received at least a visit per month. This can be viewed as an improvement over the outcome of former set-up but this achievement is well below the expectation of the T&V reform. In all, the Sri Lankan T&V model needs alterations with respect to the objective of achieving a greater extension coverage. In order to reach a wider clientele effectively, following suggestions can be stated. First, number of field extension workers at the village level should be increased as it is evident that present ratio of Farmers/Extension Worker is quite high so that execution of visit schedule has become a difficult task. Second, arrangements have to be made to strengthen the VEW - CF - FF linkages. This can be done by, utilization of informal contacts with greater care, execution of group extension methods more intense form and making all the parties well aware of the T&V concept. Third, extension workers should be freed from other duties which they take part in addition to the function of knowledge dissemination. This has a special importance because the T&V system emphasizes a condition of 'extension exclusiveness' but evidence show that, in actual situation, still VEWs shoulder other responsibilities. Finally, the time-bound, strict work programme has to be made more flexible to deal with day-to-day activities and at the same time supervision of the field staff also should receive careful attention. In fact, field supervision has to be intensified.

In the global context, the T&V approach has gained a considerable popularity in developing countries. Approximately a decade has passed since the introduction of the system to the peasant sector of Sri Lankan agriculture. Empirical realizations are, in fact, seriously limited, except the evaluationary work undertaken by the executing agency. However, it seems that investments are being continuously made available to stabilize the system. Two crucial issues can be forwarded at this point. First, with present hierarchically organized extension net-work, is the system really reaching the small farmers effectively and further, are the extension 'offerings' client oriented ? Second, in the long run, can the system generate reasonable return to the investment? During the past, many extension approaches failed to serve small farmers although heavy investments were directed towards the implementation such approaches. It is evident that in many instances, extension programmes were put into practice without much empirical support but prejudice in favour of the success. On the other hand, it has to be mentioned that whatever a strong strategy may not produce expected outcome if necessary conditions are insufficiently fulfilled. Such situations will undermine the deliberate objectives of an approach, indeed.

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SOCIAL SCIENTIST : HIS ROLE IN THE INTRODUCTION OF AGRICULTURAL INNOVATIONS IN DEVELOPING COUNTRIES

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SUMMARY

Social scientists such as sociologists, anthropologists, educationists and social psychologists have an important role to play in the introduction of agricultural innovations. Adoption by farmers of agricultural innovations is only part of a process which also requires changes in knowledge, attitude and skills. Socio-cultural factors often outweigh economic factors when a drastic change in production practice is involved. A trained social scientist could make useful contribution in research and fact finding, planning, implementation and evaluation of the extension programme designed to introduce agricultural innovations in developing countries.

INTRODUCTION

Agriculture is the major sector of the economy of most developing countries and also carries the highest potential for development in terms of both production and employment. The farming sector is generally characterized by small family farms and traditional farming operations. Modernization of this sector will depend, in part, on the adoption by farmers of appropriate agricultural innovations. By an innovation, we mean an idea or a practice that is perceived as new by an individual. So far as agriculture is concerned, an innovation may be considered to be a farming practice that is perceived as new by farmers. This paper attempts to describe the role of social scientists such as sociologists, anthropologists, educationists and social psychologists in the planning and implementation of an extension programme to introduce an agricultural innovation into the farming community of a developing country.

CHANGE PROCESS

Change in farmer behaviour reflected by the adoption of agricultural innovations is only part of a process which also requires changes in knowledge, attitude and skills (Dudhani and Ganapathy, 1975). It is assumed by and large that knowledge of people is to be enriched as a pre-requisite for subsequent changes. The second aspect of change to be brought about is the change in attitude. It may also be argued that change in attitude should precede enrichment of knowledge. Change in action usually follows after changes in thinking and attitudes have occurred. In order to establish a new habit, one needs to develop the ability or skill of that habit. New skills are learned when changes have taken place in attitudes.

IMPORTANCE OF SOCIO-CULTURAL FACTORS

During the past two or three decades, most of the developing countries have been trying to speed up their rates of agricultural development and social change, often with the help of international organizations and the more advanced countries. The assistance has come in two forms -- economic assistance in the form of loans and grants, and technical assistance in the form of advisers in a variety of fields. The results of such assistance have not come up to expectations. Much of this disappointment can be attributed to the differences in social structure between the developing countries and the more advanced countries which provided such assistance.

Socio-cultural factors often outweigh economic factors when a drastic change in production practice is involved. Given below are some examples of agricultural innovations that failed due to socio-cultural incompatibility (Spicer, 1961).

The high yielding hybrid corn introduced by the agricultural extension agent into a community of Spanish-American farmers was later rejected when their families complained that it did not taste as good as the native variety. A culturally acquired taste caused the rejection of an improved technical idea.

Introduction of soyabean into Sri Lanka a couple of decades back was not very successful mainly because it did not taste "good". Thus, soya bean, although nutritive, was not readily acceptable to the people due to its "bad" taste.

The concerted efforts of agricultural extension workers to encourage farmers to rear cattle in parts of India failed due to the attitudes of Hindus towards cattle slaughter.

The wells that were needed for an assured water supply for cultivation in the Viru Valley, Peru were abandoned mainly because of the lack of understanding of the cultural factors by the government which launched this research project.

ROLE OF SOCIAL SCIENTIST

Social science has an essential contribution to make at all stages of the programme. It is important that the social scientist be involved in research and fact finding, planning, implementation and evaluation. This is of paramount importance in developing countries where little information regarding the characteristics, attitudes and values of rural farming communities is available.

In the preparatory stages of the programme, it is the role of social scientist to interpret human situations as they exist and to make predictions as to the probable social consequences of the adoption of the innovation. In the implementation of the programme he should, according to the degree of his wider understanding and experience in working with farming population, participate responsibly in decision making as to policy and action, and in problem solving. His concern throughout is with the effect of the innovation on the social structure and the sociological and psychological obstacles to change.

The social scientist could also serve in the advisory capacity and in training the change agents directly engaged in the implementation of the programme.

ASSESSMENT OF SOCIAL CONSEQUENCES

While planning the introduction of an agricultural innovation, it is necessary to remember that changes in one aspect of culture may have an effect on the other aspects of the same culture. If changes introduced in one aspect of culture are likely to have an unacceptable effect on other aspects, then the programme will eventually fail.

Since the spiritual, social, economic and technical sectors of culture are interdependent, a change in technological skills will lead to changes in social life. For instance, when the subsistence-oriented peasant agriculture is transformed into modern, market-oriented agriculture by the introduction of cash crops, the life of farmers and their families undergo vast changes : Money is coming into the household; unknown consumer goods are bought; villagers come into contact with urban life; values change; the younger generation looks for jobs outside agriculture; nuclear families live separated from their parents.

It is realized that in human relations it is extremely difficult, if not impossible, to foresee fully the possible effects of one change after another. Hence, there is no way of planning a long-term programme by a fixed blueprint. Such as is possible in constructing a highway or bridge. Nevertheless, the social scientist, as a member of the planning team, will be in a better position to explain to his colleagues the probable social consequences of introducing the agricultural innovation.

UNDERSTANDING OF ATTITUDES AND VALUES

Attitude is the predisposition of an individual to evaluate some symbol, object or aspect of his world in a favourable or unfavourable manner (Katz, 1960). When specific attitudes are organized into a hierarchical structure. They comprise value systems. If an attitude is tied in strongly with the value system, it will be more difficult to change than if it were a fairly isolated attitude of a person.

Many peasant farmers living in the rural areas of developing countries are traditionally minded and have a negative attitude towards change. It is therefore necessary to change their attitude towards change and motivate them to want new technology. Since the resistance to modern practices stems largely from traditional attitudes and values, it is advisable to understand first the reasons why people hold these attitudes, or in other words the needs that are gratified by holding these attitudes, because it is always advisable to deal with the fundamental causes rather than with the symptoms. In this context, the social scientist can make a useful contribution to the programme by identifying and explaining the nature of attitudes and values held by farmers.

For example, the strategy for changing a particular practice may have to be different depending on the basis of its adoption. If the practice is believed to be the best because it leads to good crops, one might show how another practice leads to even better crops. But, if a practice is derived from the farmer's basic ideas about the nature of the universe, the demonstration that another practice is better may not be as effective. It may be necessary to change many more elements in the farmer's cognitive system before the new practice becomes acceptable.

If the practice is "ego-defensive" it may be even more difficult to change. For instance, a farmer may have a view of himself as being exceptionally hardworking, and by using his hands in farming, he validates this view of himself. If he were to use agricultural equipment which requires him to sit on top of a machine, this may appear dissonant with his concept of being a hardworking farmer. He may thus prefer the hand tool to machine because the former supports his self-image better than the latter.

Customs or habits get established when they gratify needs. This fact is sometimes forgotten by some experts visiting a foreign culture. They tend to see customs as an exotic collection of practices rather than as expressions of important values and clues about the existance of certain needs. Admittedly, it is difficult to determine the particular needs that are served by each custom. A careful analysis, however, will be very useful.

The innovation should be compatible with the value system of the specific group of farmers whose practices it is desired or necessary to change. It is always preferable to modify the innovation to fit the value system, rather than trying to change the values of farmers -- usually with disastrous consequences-- for the sake of introducing the innovation unchanged. It is generally possible to change some features of the innovation, without sacrificing its efficacy. If erroneous and incompatible with reality, the values themselves will dissolve in the course of time, but nothing gives them life like a direct attack upon them. Their untruth has to be discovered slowly by the farmers and at the same rate at which the farmers are finding new sources of security. A difficulty with many agricultural extension programmes has been that they were based mostly on technical research findings, which should be disseminated to farmers according to the researchers, and not on the information needed to solve farmer's problems (Van den Ban, 1987).

INVOLVING PEOPLE

Another important area of fruitful collaboration between change agent and social scientist is that of formulating strategies for involving people in the programme. Each farmer chooses whether to adopt or reject a new farming practice. But, this choice is influenced, to a considerable extent, by the attitude of others in his group or community. Thus, the change agent must take into account not only the wants, desires and wishes of individuals, but also how they act and react as groups. Furthermore, in the adoption of certain practices -- for instance, soil conservation or pest and disease control -- farmers should be encouraged to act both as individuals and as groups. Agricultural extension programmes should, therefore, pay attention not only to technical agriculture but also to the development and maintenance of farmers' organizations.

Since it is practically impossible to involve all group members at the planning stage, it is useful to at least involve the group leaders. The social scientist will be of invaluable assistance in identifying the existing leadership pattern in the farming community.

The formal leadership pattern could be identified by simply noting the persons who are in selected organizations and public official positions. The informal leaders -- for example, opinion leaders -- could be identified by sociometry, informant rating, self designation, or through casual observations regarding social participation, influence, etc. Overemphasis on leaders, while neglecting the other group members, should be avoided because it is too optimistic to assume that the leaders have a complete control over the others and that when the leaders accept and adopt innovation, it will automatically be adopted by the other members of the community. Also, it is best not to refer to persons as leaders all the time, as such term may weaken the relationship between a leader and his group.

LOCATING AND UTILIZING EXISTING COMMUNICATION CHANNELS

A trained soical scientist is equipped with the knowledge that enables him to make a thorough analysis of the channels and techniques of communication that exist in rural communities. Examples of such local channels are : womenfolk gossiping at the village well; men gossiping at liquor shops and at threshing floors; news and views exchanged at the market, at funerals and during religious festivals; the homes of carriers of prestige where people gather for up-to-date and authentic information on various topics; the village writer who specializes in writing petitions, letters and the like for illiterate folk, etc.

Knowledge of these channels of communication should be had before the programme is launched because the gossip group can be used to develop suspicion and hostility against the programme as well as receptivity for it. To understand these types of communication channels is as important as the knowledge of physical roads and paths leading to rural areas. These existing local channels should be identified and those appropriate should be utilized favourably in the programme.

SELECTION OF COMMUNICATION METHODS

People resist changes that they do not understand. Thus, it is important to find out whether the resistance of farmers to changes arises due to the specific innovation or the type of communication method used in the programme. Farmers will resist an innovation even if it is otherwise acceptable, if it is introduced by communication methods that are not acceptable to them. When the resistance against the method of introducing an innovation is allowed to develop, it may become organized so that farmers' energies are channeled into opposition to the programme, while the innovation itself becomes the symbol of that opposition. A thorough study of the means of communication is therefore essential and this field holds out challenging possibilities of social science research in developing countries.

Every means or type of communication has two aspects : the tangible, physical or material aspect; and the less tangible, social or psychological aspect. The former differs little whereas the latter differs a great deal from culture to culture (Maunder, 1973). Change agents while planning and implementing an extension programme usually take into account mainly the material aspect of the means of communication with little or no emphasis on the social aspect. The social scientist can assist the change agent by pointing out this social or psychological aspect. For instance, the use in a farmer training class of an illustration based on a pig to show the essentials of good feeding will certainly defeat its own purpose if used in a muslim community.

The social scientist has to remind the planners that the channels and techniques of one culture may not function effectively if they were introduced into another culture. To illustrate written literature is of little value among farmers who are highly illiterate; yet, in developing countries, we have some authorities indulging in the production of bulletins, pamphlets and the like to be used in extension programmes among peasant farmers who are illiterate.

Also, although the major purpose of the programme is the same, to be effective in reaching different types of audience-- for instance different adopter categories -- the message design, treatment and presentation should be tailored to the group's socio-cultural perceptions.

TRAINING OF CHANGE AGENTS

The change agent coming into a farming community to serve for a limited period of time does not really "belong" to the community. He does not fit neatly into the established pattern. Since he is a government official, people might suspect his duties to be similar to that of a tax assessor. Each change agent, however, has a considerable opportunity to influence how he is ultimately perceived and accepted by his clients.

It is pertinent to note that an individual's inclination to accept the recommendations made by the change agent will depend on the credibility of the latter (Hovland, Janis and Kelly, 1953). These writers consider the credibility of a change agent to be the resultant value of : 1) his "expertness" -- the extent to which the change agent is perceived to be a source of valid assertions, and 2) his " trustworthiness " -- the degree of confidence in the change agent's intent to communicate the assertions he considers most valid.

The change agent, to be effective, should therefore endeavour to establish credibility and good relationships with his clients before organizing programme activities. In this context, participation of the social scientist in training programmes for the change agents should be encouraged. He can make a distinct contribution to the success of the programme by offering his concrete, practical insights about human behaviour. Some useful ways for building credibility are : to be honest and sincere; to keep up promises; to listen attentively to what people say; to be willing to work with clients rather than for clients; to be thorough with the subject matter; and to start with something that can be achieved relatively quickly and easily.

The interaction between change agent and a group of farmers may usefully be seen as an interaction between members of two different groups with different values and attitudes in respect of farming topics. The change agent has had a scientific training which leads him to regard evidence as valid only if it is supported by experimental data. Most of the farmers, on the other hand, have had no scientific training and regard their own experience as valid evidence. When a farmer says " I have tried all pesticides for rice leaf roller and none of them are any good," what he means is that he had used them all at different times and in different seasons. This is valid evidence of the uselessness of these pesticides for the control of rice leaf roller for the farmer but not for the change agent. The farmer believes that the pesticides are no good; the change agent believes that the pesticides are effective -- there is experimental evidence for this -- but that they are not being used properly.

If the change agent continues to press his point of view, this will be interpreted by farmers as a challenge of their abilities or knowledge, and consequently they may become ego-defensive (Tully, undated). The change agent should, therefore, be very careful in discussing with farmers, to ensure that he does not provoke ego-defensive responses as this will reduce the possibility of inducing favourable change in behaviour on the part of farmers. Farmers resent being pushed around and told what to do. They resist being forced to change. They want to be treated as human beings -- as intelligent, responsible persons. To most of the farmers in developing countries farming is a way of life. Their values generally include enjoying living in their villages among the relatives and friends, being independent and proud of their farming skills. They can accept help and advice only to the extent that doing so does not violate their own self respect.

Also farmers learn more easily from "reciprocal colleagues" than from teachers (Mosher, 1978). The reciprocal colleague is an equal who is a teacher on some occasions and learner on others. The change agent should not, therefore, take the attitude of a teacher or a superior, but should be a reciprocal colleague, that is one who learns from as well as teaches to farmers.

The change agent is knowledgeable about agricultural innovations whereas farmers possess a wealth of practical experience. For the programme to be successful, it must maintain a smooth functioning of the two-way communication process : from the change agent to farmers, the innovation, and from the farmers to the change agent, practical experience and field problems.

EVALUATION OF THE PROGRAMME

Evaluation not only helps determine the effectiveness of the programme in terms of bringing about changes in knowledge, attitude and behaviour, but also helps clarify what is being done. Since some of the changes brought about by the programme will be chain reactions, constant analysis is essential to make the necessary adjustments. Involvement of social scientist in evaluation is necessary as all the development processes have a social impact.

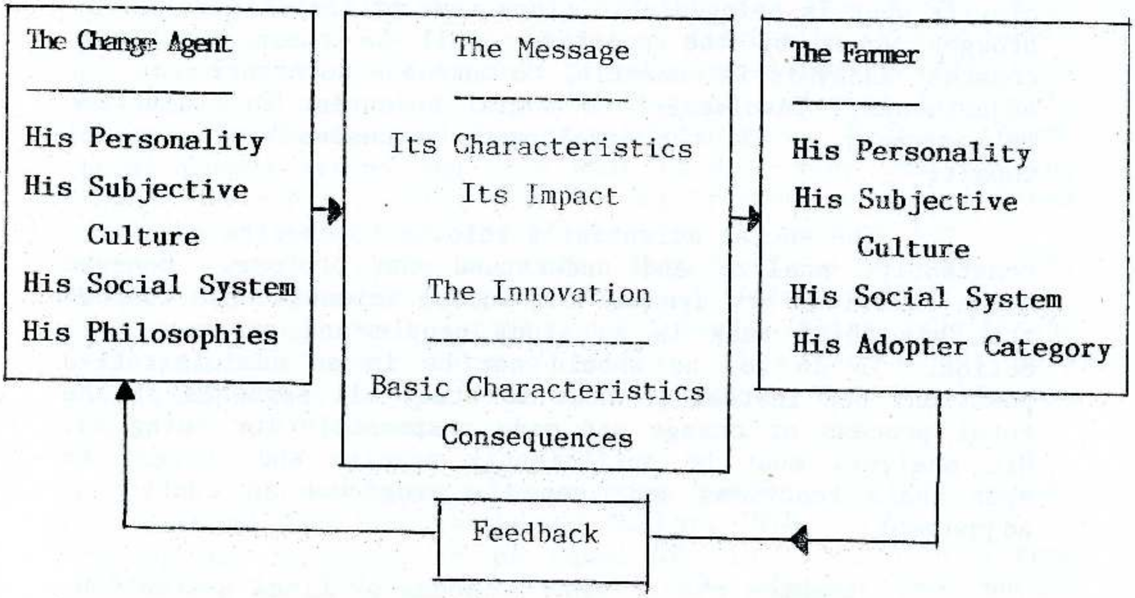
The social scientist's role is to observe constantly, analyze and understand the process. Because human relations are dynamic the social scientist has learned that his chief task is to study people and programmes in action. To do so, he should not be in an administrative position, but instead be free to study all segments of the total process of change and made responsible for doing so. His analysis must be sufficiently precise and current to spot chain reactions and keep the programme in continuous adjustment.

Attempts should also be made, by final evaluation, to not only assess the effectiveness of the programme but also analyze the social, psychological and economic trends initiated by it and their implication for the future.

CONCLUSION

The change agent, the farmer and the innovation constitute a system of three elements which are closely interrelated in any situation involving behavioural change. The " total system " that is relevant in analyzing change is represented in the following figure (adapted from Triandis, 1971).

In thinking about the optimal strategy to be employed in an extension programme designed to bring about behavioural change in a farming community by introducing an innovation, it is important to consider what change will occur in each of the above elements, and how change in one element will influence change in the others.



The knowledge of social scientists cannot be as exact as that of an engineer or a biologist, but it is felt that the officers who organize and implement the extension programmes must be increasingly aware of the assistance they can receive from those who study man and society.

In most of the developing countries, due to the acute shortage of local social scientists, we find many foreigners working in these countries as social science experts. However, the field assignments are sometimes too short for them to acquaint themselves with the conditions in which they work and to carry out an appropriate analysis and interpretation of the social problems. Furthermore, certain vital information concerning the local scene does not get to the foreign expert due to language barriers and other reasons. In order to make maximum use of these experts, they should, therefore, be given longer field assignments, and also, arrangements should be made for them to work very closely with local counterparts.

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SHORT COMMUNICATION

WEED MANAGEMENT IN BRINJAL

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Brinjal (Solanum melonjine L.) is a commonly grown vegetable in Sri Lanka. This crop is established with seedlings with a spacing of 1 m x 1 m/plant and maintained for more than eight months. The crop is prunned after 3-4 months of harvesting and the ratoon crop is maintained for another 4 months. The weed problem in brinjal is very serious due to wide spacing. Weeding is mainly by hoeing every two to three weeks. For each weeding approximately 30 labour units/ha. are needed at costs ranging from Rs. 1500 -2,000. This however, may vary with the weed population in the cropland.

At present, different methods are adopted to control weeds. Traditional methods such as hoeing, hand pulling, intercultivation and mulching with paddy straw and other crop residues etc. are practised extensively and are expensive. Pre-emergence herbicides (Saimbhi et al., 1976; Agaev and Voevodin, 1985) as well as directed application of some non-selective post-emergence herbicides with a protective hood (Saimbhi et al., 1976) have given successful weed control for brinjal in India. Saimbhi et al. (1976) have observed severe injury to transplanted brinjal plants with linuron, diuron, chloroxuron, simazine, triazine, 2-4 D and dichlormate but alachlor applied pre-emergence and paraquat, a non-selective post-emergence herbicide have given best performance. Although a potential exists, herbicides have not been used for brinjal locally due to insufficient research and the unavailability of appropriate herbicides.

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* Government Seed Farm, Pelvehera.

This study was undertaken to develop an appropriate weed control practice for brinjal grown for seed using pre- and post- emergence herbicides.

The experiment was conducted at the Government Seed Farm, Pelvehera during September, 1987 through March, 1988. The soil type was reddish brown earth (Rhodustalf). The total rainfall during the experimental period was 166.7 mm.

Brinjal variety SM-164 was grown. The following were tested as experimental treatments:

Unweeded (control)
Clean weeding (upto 12 Weeks after transplanting WAT)
Hoeing twice (3 and 6 WAT)
Hoeing thrice (3,6, and 9 WAT)
Hoeing (6 WAT) + alachlor (3.0 kg/ha a.i.) + linuron (1.5 kg/ha a.i.)
Glyphosate (1.0 kg/ha a.i.)
" + alachlor (3.0 kg/ha a.i.)
" + alachlor (3.0 kg/ha a.i.)+linuron(1.5 kg/ha a.i.)
" + metolachlor (3.0 kg/ha a.i.)
Quizalofop-ethyl (0.2 kg/ha a.i.)
" + alachlor (3.0 kg/ha a.i.)
" + alachlor (3.0 kg/ha a.i.)+linuron (1.5 kg/ha a.i.)
" + metolachlor (3.0 kg a.i.)
Glufosinate ammonium (1.0 kg/ha a.i.)
" + alachlor (3.0 kg/ha a.i.)
" + alachlor (3.0 kg/ha a.i.)+linuron(1.5 kg/ha a.i.)
" + metolachlor (3.0 kg/ha a.i.)
Fluazifop-butyl (0.375 kg/ha a.i.)
" + alachlor (3.0 kg/ha a.i.)
" + alachlor (3.0 kg/ha a.i.)+linuron(1.5 kg/ha a.i.)
" + metolachlor (3.0 kg/ha a.i.)
Hoeing (3 WAT)+mowing (6 WAT)
" +Intercultivation (6 WAT)

Treatments consisting pre-emergence plus post-emergence were tank mixed at the time of application. These treatments were assigned at 6 WAT (November 05th, 1987) following a hoeing adopted at 3 WAT.

The experimental design was a randomized complete block with four replications. Post-emergence herbicides were sprayed at 6 WAT. One meter strip in between every adjacent plot was left as an unweeded control. Weed growth in each treatment was compared with that in the adjacent control strip in addition to the unweeded (control) treatment. A protective hood was used to protect brinjal plants from the non-selective herbicide injuries.

Cultural practices were adopted as recommended by the Department of Agriculture. One-month old seedlings were transplanted in the field with 1 m x 1 m spacing on 27th October 1987. Experimental plots were fertilized with N,P and K at rates of 75, 53 and 75 kg/ha, respectively, as basal dressing. Plots were top dressed with N, P and K at rates of 38, 50 and 38 kg/ha, respectively. Ambush (3-(phenoxyphenyl)-methyl(7)-cis, trans-3-(2,2-dichloroethenyl) -2,2-dimethyl cyclopropanocarboxylate) was sprayed on brinjal plants to control leaf eating caterpillers, while captan (cis-N-(trichloromethyl)(thio)-4-cyclohexane-1,2-carboximide) was sprayed to prevent fungal diseases during the rainy period. Crop was supplementally irrigated using sprinkler system to alleviate water stress.

Collection of data was commenced at 12 WAT and continued for another 9 weeks at 3-weed intervals. All weeds were collected from a m2 area selected randomly from both experimental plot and adjacent control strip at 18 WAT. Weed dry weight% was calculated using the following equation. Since weeds were different among experimental plots in each block, weed dry weight of adjacent unweeded control strip was used as the denominator in place of weed dry weight of contrl plots.

$$\text{Percent weed dry weight} = \frac{\text{Weed dry weight in treatment}}{\text{Weed dry weight in control strip}} \times 100$$

Harvesting of mature fruits started at 15 WAT and continued for another 6 weeks. Total fruit yield, individual fruit weight/plant, total and 1000-seed weights, number of seeds/fruit and gross income (at Rs. 400.00/kg, selling price of the Department of Agriculture) were computed. Analyses of variance was performed for the data and Duncan multiple range test (DMRT) was used as a mean separation procedure (Steel and Torrie, 1980).

The highest weed dry weight of 3040 kg/ha was in the unweeded plot (Table 1). There was no significant difference in the weed dry weight between unweeded treatment and hoeing, glyphosate, guizalofop-ethyl and fluazifop-butyl treated plots. Treatments were alachlor was mixed with the above herbicides, showed a decrease in the weed dry weight. Significant decrease in the weed dry weight was found when linuron + alachlor or metolachlor added to post-emergence herbicides of glyposate, quizalofop-ethyl, glufosinate ammonium or fluazifop-butyl.

Mowing at 6 WAT (1942 kg/ha) and intercultivation at 6 WAT (2236 kg/ha) did not give any significant decrease in weed dry weight. The lowest weed dry weight of 236 kg/ha was observed in the hoeing once + alachlor + linuron treatment.

Glyphosate, quizalofop-ethyl, glufosinate ammonium and fluazifop-butyl being post-emergence herbicides controlled weeds which were present in plots at the time of application. Alachlor, metolachlor and linuron being pre-emergence herbicides controlled weeds prior to seedling emergence. Tank mixing of alachlor + linuron with the above post-emergence herbicides controlled both existing weeds and emerging weed seedlings resulting a lower weed drymatter than with alachlor or metolochlor alone. Experimental plots which received post-emergence herbicides alone had both broad-leaf, grass and sedge weeds at harvesting. The herbicides mixtures have suppressed weeds to a greater extent when compared with post-emergence herbicide alone, hoeing, hoeing plus mowing or intercultivation treatments.

Percent weed dry weight also followed a similar trend with weed dry weights. When metolachlor, or linuron + alachlor was added to the above post-emergence herbicides, weed dry weight% significantly decreased.

Table 1. Effect of Treatments on Total Weed Dry Weight, Yield and Yield Components and Gross Income of Brinjal.

Treatment	Weed Dry Weight		Fruit yield	Individual Fruit weight	Total seed yield	Seeds per Fruit	Gross income
	Kg/ha	%	Kg/ha	Kg/ha	Kg/ha	No.	Rs/ha
Unweeded	3064 a *	88.5 a	2321 bcde *	142.0 bd	31.7 e	666 b	12,680 e
Clean weeding (upto 12 WAT)+	288 e	7.3 k	4208 abc	351.9 abcd	60.0 bcde	581 b	23,995 bcde
Hoeing twice (at 3 and 6 WAT)	2690 ab	26.1 hijk	2321 bcde	258.1 abcd	65.1 bcde	862 ab	26,040 bcde
Hoeing thrice (at 3, 6, and 9 WAT)	2321 abcd	21.5 ijk	2571 bcde	262.2 bcd	44.9 cde	686 b	17,960 cde
Hoeing (at 6 WAT) + alachlor + linuron *	236 e	11.4 jk	5592 a	467.5 a	100.9 a	1288 ab	40,360 a
Glyphosate	2414 abcd	73.9 abc	2537 bcde	212.2 bcd	44.7 cde	530 b	17,880 cde
Glyphosate + alachlor	1935 bcd	48.0 efg	2900 bcde	144.5 d	34.6 e	483 b	13,840 de
Glyphosate + alachlor + linuron	713 e	35.3 fghi	2571 bcde	210.0 bcd	58.5 bcde	1070 ab	23,406 bcd
Glyphosate+ metolachlor	962 e	49.8 defg	2837 bcde	237.3 bcd	56.5 bcde	713 b	22,600 bcde
Quizalofop-ethyl	2678 ab	79.9 ab	2113 cde	182.8 cd	45.2 cde	784 ab	18.080 cde
Quizalofop-ethyl + alachlor	1860 cd	61.8 cde	3189 bcde	266.7 abcd	42.6 de	1011 ab	17,046 cde
Quizalofop-ethyl + alachlor + linuron	728 e	26.9 ghijk	3087 bcde	258.1 abcd	40.5 e	579 b	16,200 cde
Quizalofop-ethyl + metolachlor	995 e	37.3 fghi	3139 bcde	262.5 abcd	65.7 bcde	746 b	26,280 bcde
Glufosinate ammonium	2010 bcd	70.3 abcd	3984 abcd	333.7 abcd	48.3 bcde	858 ab	19,320 bcde
Glufosinate ammonium + alachlor	1940 bcd	60.7 bcde	4196 abc	350.8 abcd	80.8 ab	1519 a	32,320 ab
Glufosinate ammonium + alachlor + linuron	742 e	33.5 ghijk	4440 ab	371.3 abc	78.8 abc	848 ab	31,520 ab
Glufosinate ammonium + metolachlor	980 e	27.2 ghijk	3008 bcde	251.6 abcd	49.9 bcde	549 b	19,960 cde
Fluazifop-butyl	2461 abc	47.7 efgh	2153 cde	180.0 cd	61.7 bcde	911 ab	24,680 bcd
Fluazifop-butyl+alachlor	1661 d	78.9 abc	2919 bcde	429.7 ab	62.1 bcde	943 ab	24,840 bcde
Fluazifop-butyl+alachlor+linuron	922 e	26.9 ghijk	2970 bcde	319.6 abcd	76.5 abcd	716 b	20,600 abc
Fluazifop-butyl+metolachlor	889 e	26.2 hijk	3431 bcde	286.9 abcd	54.8 bcde	679 b	21,920 bcde
Hoeing (at 3 WAT) + mowing (6 WAT)	1942 bcd	71.1 abcd	1734 e	215.0 bcd	44.9 cde	1095 ab	17,960 cde
Hoeing (at 3 WAT) + Intercultivation (at 6 WAT)	2236 bcd	56.8 cdef	1805 de	152.2 cd	42.8 de	925 ab	17,120 cde
cv%	29.5	29.9	32.3	39.2	36.9	12.8	29.7

Results indicate that tank mixing of alachlor + linuron or metolachlor with the post-emergence herbicides and clean weeding upto 12 WAT had similar effect and were superior to all other treatments.

The highest fruit yield of 5592kg/ha was obtained with hoeing once (at 6 WAT) + alachlor + linuron combination but was not significantly different from clean weeding upto 12 WAT, glufosinate ammonium alone or when combined with alachlor or alachlor + linuron. The latter gave the lowest weed dry weight. The lowest fruit yield (1734 kg/ha) was produced by the mowing. There was no significant difference in fruit yield between glyphosate, quizalofopethyl, glufosinate ammonium and fluazifop-butyl treatments or in combination with alachlor + linuron + linuron or metolochlor. Fruit yield increased when alachlor, alachlor + linuron or metolachlor was added into post-emergence herbicides due to enhanced suppression of weeds.

The highest fruit weight of 467 g. was produced by hoeing once + alachlor + linuron which also gave the lowest weed dry weight (Table 1). The above fruit weight was not signficantly different from plots which received herbicide mixtures containing post-emergence herbicides and metolochlor or alachlor + linuron, clean weeding upto 12 WAT and hoeing twice at 3 and 6 WAT. The lowest fruit weight of 142.5 g was given by the unweeded treatment. Other treatments gave moderate fruit weights.

Similar to fruit yield and fruit weight, the highest seed yield (100 kg/ha) was recorded by hoeing + alachlor + linuron. Although not significantly different from glufosinate ammonium alone and in combination with alachlor, fluazifop-butyl when combined with alachlor + linuron, and intercultivation at 6 WAT. The lowest seed yield was produced by the unweeded treatment which could be attributed to competition. Other treatments gave equal yields.

Thousand seed weight ranged from 3.89 - 4.81 g and was not significant being a genetic character (Beatty et al, 1958).

The seeds/fruit varied with treatments. The highest seed/fruit of 1519 was from the glufosinate ammonium + alachlor but non-significant between treatments containing alachlor + linuron combination, as well as quizalofop-ethyl, gufosinate ammonium alone, mowing and intercultivation. Other treatments gave lower seeds/fruits.

The highest gross income of Rs. 40,353/= ha was from hoeing (at 6 WAT) + alachlor + linuron treatment which also had the lowest weed dry weight. Similar results were found with glufosinate ammonium + alachlor, glufosinate ammonium and fluazifop-butyl when mixed with alachlor + linuron.

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