STUDIES ON MOVEMENT AND PLACEMENT OF SYSTEMIC GRANULAR INSECTICIDES IN SOIL IN RELATION TO CONTROL OF PESTS OF PULSES

BY

C. NANDA KUMAR

THESIS

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DECLARATION

I hereby declare that this thesis entitled "Studies on movement and placement of systemic granular insecticides in soil in relation to control of pests of pulses" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

(C. NANDA KUMAR.)

Vellayani,

12th January 1981.

CERTIFICATE

Certified that this thesis, entitled "Studies on movement and placement of systemic granular insecticides in soil in relation to control of pests of pulses" is a record of research work done independently by Shri. G. Nanda Kumar, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

(Dr.(Mrs.) A. VISALAKSHI.)
Chairman
Advisory Committee
Associate Professor of
Agricultural Entomology.

Vellayani,

12th January 1981.

Approved by:

Chairman

Dr. A. Visalakshi.

Members

Dr. M.R.Gopalakrishnan Nair.

Dr. R.S. Aiyer.

Shri. S.P.Christudas.

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C. NANDA KUMAR.

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INTRODUCTION

INTRODUCTION

Systemic insecticide granules applied in soil is a commonly adopted method for the control of crop pests. This method is used not only for insects infesting various plant parts but also for the control of soil grubs. One of the unique features of systemic insecticide granules when used in soil is their capacity to move in the soil environment (Burkhardt and Fairchild, 1967; Schulz et.al., 1973). But information available on the movement of the insecticides in different types of soil is meagre. Such a knowledge would be useful in guiding the method of application of the insecticides. This will also help to get maximum benefit from the insecticides applied in soil. With these objects in view, the present studies were undertaken. In these studies, movement of three of the commonly used insecticide granules viz. phorate, carbofuran and disulfoton were studied in different types of soils of Kerala.

The efficiency of the insecticides applied in soil on the control of pest will depend upon the availability of the insecticides for the plants or insects. The availability in the case of the plants will depend upon the amount of the insecticides present or reaching the root zone. The insecticide residues concentrating in the root zone will depend upon the movement patterns of the insecticide in the soil. As the movement patterns will depend upon the placement of the insecticides, studies were undertaken in detail to find out the effect of different placements on the availability of the insecticides for the plants and their consequent effect on pest control and plant growth features including yield. The plant used in these studies was cowpea as systemic insecticides were already reported to be effective in controlling its pests, (Naresh and Thakur, 1972; Saxena et.al., 1972; Chopade, 1975; Ratanl and Labh Singh, 1977 and Rao and Rao, 1978).

Studies on the horizontal movement of the insecticides were made with reference to types of soil, dose, distance and persistence. The placements studied included broad-cast, row application and point application. The effect of different placements were assessed in terms of pest control, growth, yield, persistence and residues in pods.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

An exhaustive review has been made on the movement of insecticides in soil, control of pests of pulses by soil application of insecticides and the effect of placement of insecticides, the effect of insecticides on plant growth and yield and the residues persisting within the plant parts.

<u>Movement of insecticides in soil</u>.

Adolphi (1966) stated that horizontal movement of 5% granules of dimethoate applied to heavy clay, sandy soil or standard garden soil at a rate of 2 lb per acre was very slow.

Burkhardt and Fairchild (1967) on their studies of movement of insecticides in soil, observed that horizontal and vertical movement varied with soil type and moisture. Phorate and diazinon at 1 and 4 lb toxicant per acre exhibited less movement than aldrin and heptachlor. Three weeks after application, there was essentially no vertical movement of the organophosphorus insecticides in the row into the 4th inch below the soil surface.

Harris (1969) demonstrated the mobility of insecticides in soil by means of a standard column system and concluded that aldrin and DDT were immobile, phorate and disulfoton were very slightly mobile while diazinon and thionazin exhibited greater mobilities.

Carter et al. (1970) tested the penetration and persistence of dieldrin and heptachlor in 0.5% aqueous emulsion and chlordane in 1% aqueous emulsion applied to different types of soil and reported that the insecticide penetrated to the fifth and sixth one-inch layer in sandy soil while over 70% of the insecticide was found in the top layer in sandy loam, clay and silt soils.

After analysing the residues of DDT and its analogues, Harris and Sans (1970) revealed that residues were retained largely within the top 6 inches in uncultivated sandy loam soil while in cultivated soils, residues were fairly uniformly distributed to a depth of about 10 inches. At a depth of 10-12 inches, 14% of the total residues were recovered in cultivated light mineral soil. They concluded that the vertical distribution of residues in soil is dependent on the types of soil, the extent of cultivation and the characterstics of the insecticide. El-Refie and Zidan (1971) reported that mobility of insecticides in sandy and clay soils was affected mainly by insecticide type, application rate and soil type.

Clieth and Spencer (1971) reported that after mixing dieldrin or γ-BHC thoroughly with 0-7.5 or 7.5-15 cm layer of a sandy loam and a silty clay soil and irrigating with 10 cm of water once in a month, movement and dissipation of γ-BHC was markedly greater than that of dieldrin, especially in sandy soil where measurable amounts of γ-BHC were found at 60 cm depth.

Carbofuran granules when placed 3/4th inch deep in a mineral soil was found to show an easily detected upward movement in soil (Read, 1971). Similar upward movement of disulfoton from the level at which it had been applied in silt loam, sandy loam, sand and rice field soils, was observed by Takase et al., (1971).

Ostojič et al. (1972) stated that γ-BHC had the lowest mobility in brown forest soil, degraded chernozem and black marsh soil compared to phorate and diazinon. The mobility of phorate and γ-BHC was more pronounced in forest soil than in other soil types which showed the importance of soil absorbancy for translocation of chemicals.

Downward movement of dimethoate was slightly more extensive in loamy sand compared to silty loam and clay loam and increased soil moisture content promoted downward movement in all three soil types (Duff and Menzer, 1973).

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Schulz et al. (1973) analysed the vertical and horizontal soil cores collected 2 to 4 inches away from the original band 4 1/2 months after treatment of phorate granules at rates of 5 and 10 lb toxicant per acre and reported that residues moved in both planes.

Jain et al. (1974) determined the residues at different time intervals after application of 5% disulfoton and 10% phorate granules in furrows at sowing time of rape seed crop at the rate of 1.5 kg per hectare and obtained no residues beyond 15 cm depth. But Martin (1974) reported that most of the residues of carbofuran, fensulfothion, fenitrothion and DDT remained in the top 3 cm of the soil when the insecticides were applied at the rate of 2.24 kg per hectare to a pasture.

Suett (1975) also reported the downward movement of disulfoton and phorate when applied at 2 kg per hectare to a depth of 100 mm into a sandy-loam.

Considerable movement of AG-chlordane insecticide in soil was reported by Tafuri et al. (1977) after application of 3 kg and 6 kg ai per hectare at a depth of 10 cm in a lucerne sown field. But Sears and Chapman (1979) noted little downward movement of any insecticide into the root and soil zones after treating turf grass with chlordane at 9.0 kg ai per hectare, chloropyrifos at 4 kg ai per hectare and diazinon at 4 kg ai per hectare. 2-8% of the insecticides remained in the upper 1cm of root and soil layers.

Verma and Pant (1979) found that green and redgram seedlings grown 25 cm away from the point of application of phorate did not give any kill of the jassid (Empoasca kerri Pruthi) which revealed that the chemical could not move up to 25 cm distance and showed only slight horizontal movement. But Visalakshi et al. (1979) studied the movement of phorate in different soil types and observed maximum movement of the insecticide up to 60 cm during the first day of application. Uptake and movement of phorate was maximum in sandy soil and less in forest, laterite and red soils in that descending order while movement and uptake in alluvial soil was poor.

Control of pests of pulses by soil application of insecticides

Guyer et al. (1960) found that 2% phorate granules and 2.5% disulfoton granules at 1 to 2 lb toxicant per acre when applied to the soil with seed caused general reduction in numbers of aphids and Macrosteles fascifrons Stål., in beans (Phaseolus vulgaris).

Schwartz Jr. et al. (1961) observed that application of phorate granules at 2-3 lb and disyston at 1-2 lb at sowing time controlled Empoasca fabae Harris. and Epilachna varivestis Muls. on lima beans, where as disulfoton 5 G at 1.00 kg ai per hectare and phorate 10 G at 2.00 kg ai per hectare were effective in controlling pea stem fly Melanagromyza phaseoli in peas up to 60 days (Singh and Chhibber, 1969). Granules of disulfoton (Disyston 15 G) at 9.86 kg per hectare, carbofuran (Furadan 10 G) at 11.21 kg per hectare and phorate (Thimet 10 G) at 11.21 kg per hectare when applied at the time of planting also gave good control of Empoasca fabae on white beans (Whitfield and Ellis, 1977).

Disulfoton at 1.12 kg per hectare was found to be as effective as phorate at 2.24 kg per hectare in satisfactorily controlling Macrosiphum pisum Harris. in canning peas from plant emergence till harvest (Chisholm and Specht, 1967).

Pests like Melanagromyza sp., Ophiomyia phaseoli Tryon., Aphis craccivora Koch., Hedylepta (Lamprosema) indicata (F.) and Tetranychus urticae Koch. occurring in the early stages of asparagus bean crop were effectively controlled by soil treatments using disulfoton or phorate (Chang, 1969). Das et al. (1977) also reported that effective control of Aphis craccivora and pod borers was achieved by soil application of disulfoton granules at 1 kg toxicant per hectare at sowing combined with 0.05% fenthion spray from flowering onwards.

Gupta and Saxena (1971) reported that soil application of 10% granules of phorate, disulfoton and cytrolane and spraying the crop with carbaryl 0.25% and monocrotophos 0.05% water soluble concentrate controlled the Galerucid beetle on green gram.

Among three systemic granules tested, Saxena et al. (1972) observed that phorate at 2 kg per hectare was the best in controlling the Galerucid beetle *Madurasia obscurella* Jacoby on cowpea and moong while disulfoton at 1.5 kg was the best for urd (*Phaseolus mungo*). But Verma and Lal (1976) stated that 10% phorate granules applied at 1.5 and 2.0 kg toxicant per hectare in the soil at the start of infestation, could control the Galerucid beetle for only 13 days in cowpea.

Black gram crop was protected significantly for a month from *Ophiomyia phaseoli*, *Madurasia obscurella* and *Bemisia tabaci* Genn. attack after application of aldicarb, phorate and monocrotophos granules at 1, 1 and 0.75 kg per hectare respectively to soil before sowing (Naresh and Thakur, 1972). Ratanl and Labh Singh (1977) revealed that carbofuran and aldicarb granules applied in 2 split doses of 1 kg toxicant per hectare each and at 1.0, 1.5 and 2 kg per hectare in the subsequent year gave good protection against *Bemisia tabaci* in soybean.

Sarup et al. (1974) evaluated the biological efficacy of different insecticidal formulations against some pests of pea crop and concluded that 5% granules of disulfoton gave the best control of Aphis craccivora and Phytomyza horticola Gourean., on pea. Chopade (1975) observed that disulfoton 5% granules at 1.5 kg ai per hectare applied at sowing was more effective than phorate 10% granules in controlling the above two pests on field pea crop.

Early damage to soybean plants from Agromyzid pests could be effectively prevented by soil treatment at sowing with granules of aldicarb, phorate, disulfoton or carbofuran at 1 kg toxicant per hectare followed by 2 to 3 sprayings of 0.1% methyl demeton and 0.1% endosulfan at 15 day intervals (Bhattacharjee, 1976).

Rao and Rao (1978) found that carbofuran granules applied at sowing were effective in checking the damage by Ophiomyia reticulipennis Singh and Ipe on french bean crop.

Vyas and Saxena (1980) evaluated the bioefficacy of different systemic granules as seed treatments and soil application against stem fly (Melanagromyza phaseoli Coq.) in pea and concluded that 4% seed treatment with carbofuran was the best followed by disulfoton 5 G and phorate 10 G at 1.5 kg ai per hectare in controlling the pests till the crop was about 4 weeks.

Effect of placement of insecticide granules on pest control.

Cook et al. (1962) reported that disyston applied in the furrow with seed at 25 g per 100 feet of row proved superior to phorate in controlling the aphid (*Macrosiphum pisum* Harris) on pea. Placement of granules of disulfoton, aldicarb and dimethoate in the furrows with seed were reported by Chaudhary et al. (1976) to afford control against seed maggot (*Delia platura* Mg.) attacking soybean crop.

Pablo and Pangga (1975) tested the granular insecticides cyolane, disulfoton, phorate and cytrolane at the rate of 1.5 kg ai per hectare which when applied in the furrow prior to sowing and a second application just before flowering controlled *Ophiomyia phaseoli*, *Aphis craccivora*, *Mocis undata* F., *Spodoptera litura* F., *Plusia* (*Chrysodeixis*) *chalcites* Esp., *Etiella zinkenella* Treit. and *Tetranychus urticae* in mungo bean crop in the early stages of crop growth.

Chaudhary et al. (1977) observed that 10% aldicarb granules at 1 kg ai per hectare applied to the furrow at planting and again as a side dressing 5 weeks after germination was better than similar applications of granules maintaining 10% phorate, nephospholan or carbofuran in controlling stem miner (*Melanagromyza sojae* Zehntner) and white fly

(*Bemisia tabaci*) on soybean.

In-row application of aldicarb granules at 2 lb toxicant per acre at sowing gave complete control of *Aphis fabae* Scop. on broad beans up to 7 days before harvest (Skrentny and Ellis, 1970). Chang (1971) also obtained control of Agromyzid pests infesting early stages of soybean crop by row application of granular disulfoton and phorate.

Application of Nia 10242 (2, 3-dihydro-2, 2-dimethyl 7-benzofuranyl methyl carbamate) granules applied as a side dressing gave control of pests on soybean for the whole season (Turnipseed, 1967). Hanifa et al. (1976) also stated that disulfoton, mephospholan (Cytrolane) and metalkamate (Bux) when applied at rates of 1.25 kg toxicant per hectare as a side dressing were effective in controlling pod borers *Heliothis armigera* Hb., *Maruca testulalis* G. and *Melanagromyza obtusa* M. on redgram.

Dupree (1970) found that application of dimethoate, disulfoton, phorate and a mixture of thionazin (Zinophos) and phorate were more effective when concentrated in a 2-inch band rather than a 14-inch band in controlling thrips and bean leaf beetles on lima beans. But Todd et al. (1972) showed that granular application of carbofuran and aldicarb both at 2 lb toxicant per acre in an

18-inch band over the row and incorporated into the soil with a power driven rotary tiller and a foliar emulsion spray of Du Pont 1410 at 4 lb resulted in significantly fewer *Epilachna* adults.

Effect of insecticides on plant growth and yield.

Guyer et al. (1960) ascribed the application of phorate granules at the rate of 2 lb per acre as pre-planting side dressing to the increased yields of beans.

Schwartz Jr. et al. (1961) reported that yield of lima beans was not affected by application of 2-3 lb phorate and 1-2 lb disyston granules at sowing time. Contrary to this, Webster and Smith (1962) revealed that application of disyston and phorate at 2 lb per acre in open seed furrows increased yields of fresh lima beans significantly.

Turnipseed (1967) observed a yield increase in soybean after a granular application of Nia 10242 (2, 2-dihydro-2, 2-dimethyl-7-benzofuranyl methyl carbamate) at about 2 lb per acre.

Broadcast application of disulfoton and fensulfothion increased the yields of field beans by 100-200 lb per acre but the increases were not significant (Hagel, 1970).

Wheeler and Bass (1971) found that application of disulfoton, phorate and carbofuran at 1 lb toxicant per acre in the furrow at sowing or as a side dressing at 'layby' did not increase the yields significantly.

Placement of cyolane, disulfoton, cytrolane and phorate at 1.5 kg ai per hectare in furrows prior to sowing of mungo bean and a second application just before flowering resulted in treated plants growing taller than untreated ones excepting those receiving phorate treatment and the yields were higher, though not significantly (Pablo and Pangga, 1973).

Chelliah (1972) found that application of phorate and disyston at normal dose, slightly increased growth, nodulation and yield of black gram and nitrogen content of plants and seeds but at twice the normal dose had slight adverse effect on the above characters.

That thimet at 10-40 ppm increased nodulation in broad beans in 30 days was reported by Gawaad et al. (1972) and was supported by Adel-Salam et al. (1972) who also found that nodulation in broad beans and peas was stimulated by application of phorate and disulfoton. But according to Swamiappan and Chandy (1975), eventhough phorate enhanced nodulation in cowpea by 313% over the untreated check, the weight of nodules did not progressively increase with the increase in number of nodules.

Hoffmann (1971) found that disulfoton granule treatment at a dosage of 1.5 and 3.0 kg per hectare had no effect on plant growth and yield in bean plants (Phaseolus vulgaris). Shehane and Bass (1974) showed that phorate at the rate of 1 lb per acre had little or no effect on growth and yield of soybean plants. But Moody and Bailey (1974) pointed out that disulfoton, phorate and carbofuran had enhanced plant height of soybean.

A combination of phorate at 1.5 kg toxicant per hectare applied to soil at sowing and 0.07% endosulfan spray at pod formation increased the plant weight of moong and arhar crop (Verma and Pant, 1975).

Das et al. (1975) observed that cowpea crop in plots where soil treatments with granular phorate, carbofuran and disulfoton at 3 different doses viz. 1.0, 0.75 and 0.5 kg ai per hectare were given, registered significantly higher yields than untreated.

Thimet and solvirex applied in soil at recommended dose, half and double the dose did not affect significantly the nodule number in rhizobium treated redgram but root length was increased by solvirex treatment whereas thimet paralleled control (Anonymous, 1976 a). Similar treatments with blackgram revealed that thimet increased the nodule number over control while application of double the dose of solvirex reduced the nodule number. Furadan treatments did not register significant differences due to different doses. Thimet decreased the root weight, shoot length and yield but did not increase the plant weight while furadan and solvirex treatments had a pronounced effect on plant weight (Anonymous, 1976 b).

Better nodulation was induced in rhizobium treated greengram with similar treatments of furadan, solvirex and thimet applied at the recommended dose (Anonymous, 1976 c).

Hanifa et al. (1976) found that higher yield of redgram was obtained when disulfoton 5% granules and phorate 10% granules were applied at 1.25 kg ai per hectare as a side dressing 45 days after sowing.

Oblisami et al. (1976) revealed that nodulation, shoot and root length and dry weight of groundnut plants were not adversely affected by the application of granular insecticides. Oblisami and Balaram (1976) also reported that carbofuran at the recommended dose caused an increase in the number of nodules of peanut plants on the 30th day after application of the insecticide.

Das et al. (1977) also reported that a combined treatment of soil application of disulfoton granules at 1 kg toxicant per hectare at sowing and 0.05% fenthion spray applied from flowering onwards resulted in a significantly higher yield in cowpea (Vigna sinensis).

Ratanl and Labh Singh (1977) observed that application of granules of carbofuran, aldicarb and fensulfothion at 1 kg toxicant per hectare and in the next season at 1, 1.5 and 2 kg per hectare respectively in soybean fields resulted in significantly higher yields than no treatment; carbofuran treated plots recorded the highest yields.

Visalakshi (1977) also reported that in cowpea plants, application of phorate with seed increased the plant height and root length, but decreased fresh weight and stimulated nodulation, size of nodules and fresh weight and dry weight of nodules.

But Whitfield and Ellis (1977) reported that application of disulfoton as 9.86 kg per hectare of disyston 5 G, carbofuran as 11.21 kg per hectare of furadan 3 G and phorate as 11.21 kg per hectare of thimet 10 G at the time of planting did not give increased yields in soybean and white beans.

Visalakshi et al. (1978) assessed the effect of ten insecticide granules on nodulation and growth characterestics of cowpea and showed that carbofuran, carbaryl and quinalphos increased the nodules significantly and an increase in size of nodules was also observed by all insecticides except quinalphos. Carbofuran, carbaryl and chlorodimefon increased plant height whereas weight was enhanced by carbofuran and MIPC.

Residues of insecticides in pulses.

Cook et al. (1962) observed residues of 0.07 to 0.4 ppm in peas and upper part of the pea plant after placement of disyston 5% granules in the furrow with the seed. But Webster and Smith (1962) could not detect any residues in lima beans at harvest after application of phorate and disulfoton to open seed furrows covered with 3 inches of loose soil.

Skrentny and Ellis (1970) found that after an in-row application of aldicarb and thionazin granules at 2 lb toxicant per acre at sowing of broad bean crop, less than 0.01 ppm thionazin and approximately 0.09 ppm total residues of aldicarb - sulphone and sulphoxide were obtained in bean seeds and pods 90 days after application of insecticides.

Satpathy et al. (1974) applied phorate and disulfoton at 2 kg toxicant per hectare to brinjal and cowpea and observed the levels of the insecticide residues in fruits to be above the U.S. tolerance limit of 0.75 ppm for more than 20 days after application. Higher concentrations of residues were detected in the leaves and stem than in the fruits.

Wilson and Oloffs (1974) in a field experiment applied a chlordane insecticide Velsicol HCS-3260 to soil at 5.6 and 11.2 kg per hectare and observed the levels of the parent compound and metabolites in the edible portion of beans for two growing seasons after application to be lower in the soils treated at the lower rate. In the next year also, beans contained the same residue level.

Bhattacharjee et al. (1975) investigated residues of 3 granular insecticides applied in furrows mixed with soil before placement of soybean seeds followed by a second application 4 weeks later as a side dressing. Thimet 10 G applied at 2.5 g per m row gave 2.50 ppm phorate residues in pods 65 days after application in the spring crop and 0.05 ppm in the pods in Kharif crop. Disyston 5 G @ 5.5 g per m row left residues of 1.38 and 0.17 ppm and furadan 3 G @ 5.5 g per m row left residues of 1.1 ppm and non-detectable levels on the 65th day after application for spring and Kharif crops respectively. At 85 days, there was no detectable residues in leaves, straw or grain for any of the 3 insecticides.

Pandey et al. (1975) detected insecticide residues in pea plant up to 95 days after application of 5% granules of disulfoton at 1.5 kg per hectare but noted that the insecticide was not translocated to the pods and seeds and concentrated in leaves and buds.

Enzymatic assay of phorate residues in cowpea following application of the insecticide as granules with the seed at planting at 1-3 kg toxicant per hectare revealed that residues persisted for up to 49 days and no residues were detected after 56 days either in leaves or in pods (Visalakshi et al., 1976).

After granular application of disulfoton at 1 kg ai per hectare in soil 30 days after sowing of blackgram, greengram and cowpea, Rajukkannu et al. (1977) detected residues of 0.32 ppm in tender cowpea fruit samples, 0.43 ppm in blackgram grain and 0.52 ppm in greengram grain at 65th day after sowing. At 40 days after application of insecticide, 0.18 ppm of the insecticide residue was detected in cowpea pods.

Talekar et al. (1977) observed that after soil treatment of labelled ^{14}C-carbofuran and ^{14}C-phorate, both the insecticides were readily translocated to the leaves of 2 week old seedlings of both soybean and mung bean. Measurable but insignificant amounts of radiocarbon were present in the seeds of plants grown in treated soil.

Handa et al. (1978) obtained excessive residues on soybean leaves and pods 65 days after a soil application of 10% granules of phorate at a rate of 1.5 g/M row, 5% granules of disulfoton at 2.5 g/M row and 3% granules of carbofuran at 5.5 g/M row. Residue levels were safe after 80 days and were undetectable at harvest.

MATERIALS AND METHODS

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MATERIALS

Insecticides

Phorate: O, O-Diethyl S-(ethyl thiomethyl) phosphorodithioate.

Chemical formula: $C_7 H_{17} O_2 PS_3$

Technical grade of phorate (98.7%) and Thimet 10 G (granules containing 10% active ingredient) supplied by M/s. Cyanamid India Limited, Bombay, were used for the experiments.

Disulfoton: O, O-Diethyl S-[2 (ethylthio) ethyl] phosphorothiolothionate.

Chemical formula: $C_8 H_{19} O_2 PS_3$

Technical grade of disulfoton (98.6%) and Solvirex 5 G (granules containing 5% active ingredient) supplied by M/s. Sandoz (India) Limited, Thane, Bombay, were used.

Carbofuran: 2, 3-dihydro-2, 2-dimethyl-7-benzo furanyl methyl carbamate.

Chemical formula: $C_{12} H_{15} NO_3$

Technical grade of carbofuran (99%) supplied by FMC Corporation, New York and Furadan 3 G (granules containing 3% active ingredient supplied by Rallis India Limited, Bombay, were used.

Seed: Cowpea (Vigna sinensis L.) variety 'New Era' of 70-80 days duration with a bushy growth habit was used for the experiments.

Soils: Four soil types of Kerala were collected from the different tracts as noted below:-

Sandy soil - Kayamkulam, Alleppey District

Alluvial soil - Moncompu, Alleppey District

Red soil - Vellayani, Trivandrum District

Laterite soil - Trivandrum, Trivandrum District.

These soils have the following physical and chemical properties:

Types of soil	Clay content (%)	Silt content (%)	Cation exchange capacity me/100g of soil	Organic matter content (%)	pH
Sandy	6.0	4.0	4.0	1.55	5.8
Alluvial	26.2	15.2	24.2	6.2	4.2
Red	10.9	9.2	6.5	0.5	6.5
Laterite	12.3	8.9	6.2	1.6	6.1

Manures and Fertilizers:

Cowdung, urea, super phosphate and muriate of potash with 46 per cent N, 16 per cent P_2O_5 and 60 per cent K_2O respectively, were used for the trial.

METHODS

Studies on horizontal movement of systemic insecticides in different soil types.

The horizontal movement of systemic insecticides in different soil types was ascertained in terms of the mortality of adults of *Aphis craccivora* Koch. confined on cowpea seedlings raised in concrete trays at different distances from the point of application of the insecticides.

Concrete trays of size 1 m^3 were filled with the respective soil to a depth of 30 cm. Cowpea seeds were sown at 10, 20, 40, 60 and 80 cm from the point of application of insecticide granules. In each tray, the distances were replicated twice. Uniform moisture level was maintained in all the trays.

The insecticides were applied at 2 dosages as detailed below:-

Phorate: 1 and 2 gm of Thimet 10 G were applied per tray to give dosages of 1 and 2 kg ai per hectare.

Disulfoton: 2 and 4 gm of Solvirex 5 G were applied per tray to give dosages of 1 and 2 kg ai per hectare.

Carbofuran: 1.67 and 3.34 gm of Furadan 3 G were applied per tray to give dosages of 0.5 and 1 kg ai per hectare.

The granules were applied at the previously fixed points, 10 days after sowing the cowpea seeds. Twentyfour hours after the application of the granules, 10 aphids were released on each seedling and the seedlings were separately enclosed in cylindrical wire mesh cages with the top covered with fine muslin cloth. The mortality observations were recorded after 24 hours. Subsequently aphids were released on the seedlings on the second day and fourth day after placement of the granules and mortality observed at 24 hours after release of the aphids.

Assessment of horizontal movement and uptake of phorate by cowpea plants of different ages grown in red soil.

This was assessed by applying phorate at a fixed point in the soil where 10, 20 and 40 day old cowpea plants were grown at distances of 20, 40, 60 and 80 cm from the point of application. Mortality observations were made after the release of aphid on the plants on the 1st, 2nd and 4th day after application of the insecticide.

Assessment of vertical movement of systemic insecticides in soil.

The vertical movement of phorate and disulfoton was was studied in the red soil at Vellayani. Micro plots of 1.5 square metre size were selected in the field and bunded on all 4 sides .

Application of insecticides:

The insecticides were applied at 1 kg ai per hectare as broadcast and as point application. The vertical movement was assessed at depths between 5 to 10 cm, 10 to 20 cm and 20 to 30 cm by estimating the quantity of insecticide at the above mentioned depths. The movement was studied on the 1st, 3rd and 7th day after application of the insecticides. The moisture level was maintained at field capacity. The soil samples were drawn by means of an auger.

Point application:

The insecticides were applied at 2 points at 2 cm depth from the surface, 1 metre apart in the plot. Soil samples were collected by inserting the auger vertically and in line with the point of application of the insecticide to the required depths, on the first, third and seventh day after application of the insecticide. The insecticides applied at 2 cm were removed before inserting the auger, by removing the first 5 cm of soil from the surface.

Broadcast application:

The insecticides were broadcasted uniformly in the plots. Samples were drawn as in the above case at 2 separate points from the plots after removing the 5 cm surface soil.

Estimation of residues of phorate and disulfoton in soil

Colorimetric estimation of residues in soil:

Phorate and disulfoton residues in soil were determined colorimetrically following the procedure developed by Getz and Watts (1964) as modified by Jain et al. (1974).

The soil samples collected were air dried and sieved through a 2 mm sieve. Samples of 25 grams each were separately weighed and used for the study.

A standard solution of the insecticides containing 10 μg/ml in acetone was prepared from a stock solution of 1000 μg/ml. 0, 0.5, 1.0, 1.5, 2.0 and 2.5 ml of this standard solution were taken separately in B 19/26 test tubes. A drop of propylene glycol was added to the solution in each tube and the solvent removed by blowing air from a hair drier. 0.4 ml each of benzyl pyridine and cyclohexylamine solutions were added to each tube. Air condensers were fitted to the test tubes and the tubes were heated exactly for 3 minutes in an oil bath at 175-180°C. The tubes were cooled in an ice water bath for half a minute. The air condensers were removed and 3 ml ethyl acetate was added to each tube. The colour developed was read at 540 mμ.

A regression equation Y = ax + b was obtained using absorbance and concentration in μg and this was used for the residue estimations.

Extraction of phorate and disulfoton residues in soil.

Twentyfive grams each of the air dried soil samples was taken in 100 ml beakers and 0.5 ml ammonia solution was added. It was well stirred and kept in the open till the smell of ammonia disappeared and 0.5 g of activated charcoal and 0.5 g of florisil were then added and mixed with the samples. This mixture was packed well in a column containing cotton pad at the bottom with 5 cm layer of anhydrous sodium sulphate above. The soil was eluted with 100 ml acetone. The rate of flow was so adjusted that the elution was completed in about 3 hours. The volume of each acetone extract was made up to 100 ml in a volumetric flask.

Estimation of phorate and disulfoton residues in soil.

An aliquot of the acetone extract was taken for developing the colour. The aliquot was adjusted by taking larger quantities of the extract in a Kuderna Danish evaporator and distilling off the solvent after adding a drop of propylene glycol. Then the colour was developed as explained earlier.

The amount of the insecticide residue was determined with reference to the regression equation. Applying the corresponding dilution factor, the amount of residue was calculated.

Regression equations for phorate and disulfoton in red soil were

$Y = 0.233x - 0.0277$ and

$Y = 0.273x - 0.0579$ respectively.

Bioassay of insecticide residues in soil.

The residues of the insecticides, phorate and disulfoton were estimated biologically using adults of *Drosophila melanogaster* Meign. as the test insect.

Rearing of *Drosophila melanogaster*:

The test insect was reared on an artificial diet in a B.O.D. incubator at a temperature of 26 ± 1°C and a humidity of 85 to 90 per cent.

Ingredients of artificial diet:

Agar agar	20 gm
Jaggery	65 gm
Corn flour	75 gm
Yeast tablets	3 gm
Vitamin tablets	15-20 Nos.
Propionic acid	2-4 ml
Distilled water	1 litre.

The Agar agar and corn flour were mixed in 750 ml of distilled water and cooked for 15 minutes. Jaggery dissolved in 250 ml water was poured into the mixture and boiled well. The powdered yeast tablets were added to the medium and allowed to boil. Powdered vitamin B tablets were then mixed and just heated. The media was removed from flame, 3 ml of propionic acid was added and mixed well.

The porridge was poured into clean dry jars (30 cm x 8 cm) to a height of about 2 cm. When the medium had cooled and solidified, the water droplets condensed on the surface of the media and the inner surface of the jars were wiped with a piece of tissue paper. About 15 to 20 adults of the test insect were introduced into each jar for egg laying and closed with fine muslin cloth. One day old unsexed adults were used for the bioassay.

Determination of the residues using *Drosophila melanogaster*.

The residues were determined by the dry film technique using the same cleaned up extracts used for colorimetric estimation. One ml of the solution containing the insecticide was evaporated within a glass test tube (20cm x 2.5cm) by rotating the tube to spread the solution uniformly on the inner surface of the tube to a height of 19.5 cm. After the solvent had evaporated completely, 20 adults were released into the tube and closed with muslin cloth.

Mortality observations were taken at the end of 8 hours. The quantity of insecticide residues in the samples was calculated by refering to the regression equation.

Standard solutions of phorate and disulfoton containing 0.4, 0.2, 0.1, 0.05 and 0.025 ppm were prepared and taken in test tubes. The solvents used for those were the cleaned blank extracts of red soil. The mortality counts were corrected by using the Abbot's formula $\frac{u - t}{100 - u} \times 100$ where u = mortality in untreated and t = mortality in treated sample. The corrected mortality percentage was converted to probit values (Finney 1964) against log. concentration. Then the straight line relationship was obtained by working out the regression.

Regression equations for phorate and disulfoton in red soil were,

$Y = 0.9716x + 4.320$ and

$Y = 1.657x + 3.185$ respectively.

Field experiment to study effect of placement of insecticide granules in soil on control of insect pests of pulses.

A field experiment was conducted at the Agricultural College Instructional Farm, Vellayani, to study the effect of placement of insecticide granules in soil on control of insect pests of pulses. The experimental area was lying fallow for the past 8 years. The experiment was conducted during November to February 1979-1980. The soil was a typical red soil of Vellayani, the chemical and physical composition of which has already been given.

Experimental design:

A randomised block design was adopted. The experiment comprised of 25 treatments which were replicated 3 times. There were 2 doses per insecticide. The placement was of 4 types (as given in Fig. 1).

a. Broadcast

b. In between rows (9 rows)

c. In between alternate rows (5 rows)

d. Point application (in between 4 plants at 16 points).

Dosage of insecticide:

7.2 and 14.4 grams of phorate and 11.52 and 23.04 grams of disulfoton were applied per plot under the 4 placements to give a dosage of 1 and 2 kg ai per hectare respectively. In the case of carbofuran, 9.62 and 19.24 grams were applied to give a dosage of 0.5 and 1.0 kg ai per hectare.

Total number of treatments in one block	: 25
Number of blocks	: 3
Total number of plots	: 75
Gross plot size	: 2.4m x 2.4m
Net plot size	: 1.8m x 1.8m

Fig. 1 Different placements of insecticide granules phorate, carbofuran and disulfoton.

a. Broadcast

b. In rows

c. In between alternate rows

d. Point application (in between 4 plants)

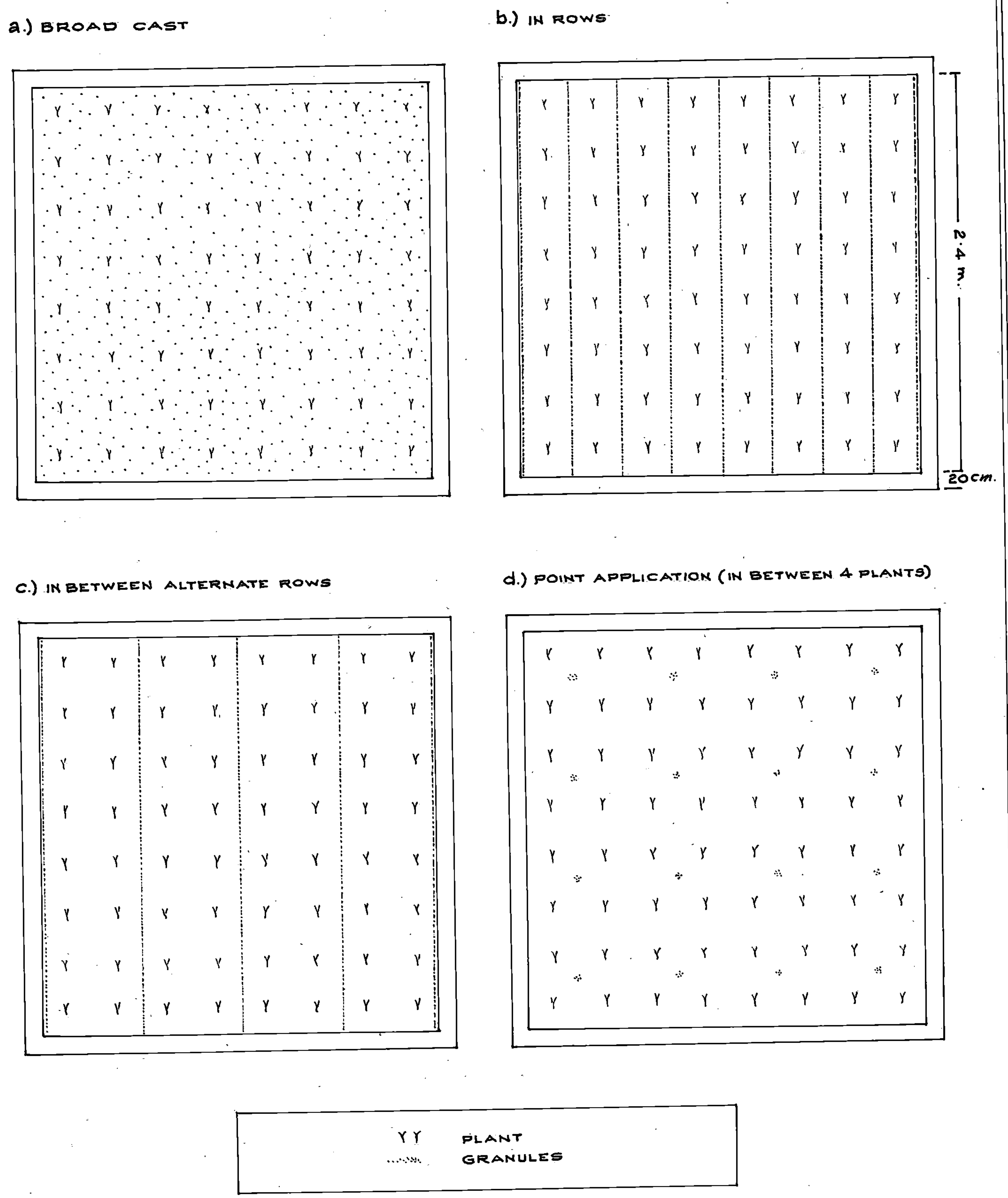


FIG. 1. DIFFERENT PLACEMENTS OF INSECTICIDE GRANULES.

Net area of the plot	:	3.24 sq.metres
Total experimental area	:	639.36 sq.metres
Spacing of crop	:	30 x 30 cm
Number of plants in gross plot	:	64
Number of plants in net plot	:	36
Number of border rows	:	1
Date of sowing	:	23--11--1979.

Preparation of plots:

Plots of size 2.4 m x 2.4 m were laid out with 25 plots in each block. Each plot had a bund at 20 cm and a channel of 20 cm which separated 2 successive plots. Individual plots were dug, clods broken and perfectly levelled.

Application of manures and fertilizers:

Dried and powdered cowdung was applied to each plot at the rate of 1.25 kg per plot. Urea, superphosphate and muriate of potash were applied to each plot so as to supply nutrients at the rate of 20 kg N, 30 kg P_2O_5 and 10 kg K_2O per hectare respectively. The manures and fertilizers were applied at the time of sowing.

Sowing of the crop:

Cowpea seeds were sown in the experimental plots with one seed at one point in rows at 30 x 30 cm spacing.

Application of insecticide granules:

The granules were applied on the tenth day after sowing as per the treatment schedule.

Field culture:

The cultivation practices as recommended in the Package of Practices of the Kerala Agricultural University (except Plant Protection) were followed.

Effect of insecticide treatments on the natural pest incidence.

The incidence of the important pests occurring in cowpea was recorded at different intervals, after application of the granules.

Observation on leaf miner (*Phytomyza horticola* Goureau) infestation:

Randomly selected 10 plants from 3 alternate rows were observed on the 10^{th} day after application of insecticide granules. Number of plants infested by leaf miner was recorded as a percentage and the procedure adopted was similar to that described by Naresh and Thakur (1972).

Observation on pea aphid (*Aphis craccivora* Koch.) population:

The number of aphids were noted on the 20th day after application of insecticide granules. For this, 5 plants were selected at random and tagged. In each plant, the number of aphids was counted in the apical 5 cm length of the shoot.

<u>Observations on flea beetle (unidentified) damage</u>:

The flea beetle damage was assessed by counting the number of holes made by the adult beetle per 10 trifoliates selected at random on the 30th day after application of insecticide granules following the procedure of Naresh and Thakur (1972) for galerucid beetle damage on blackgram.

<u>Observation on leaf webber (*Nacoleia vulgalis* Guen.) damage</u>:

Twenty trifoliates from each plot were observed at random on the 20th day after application of insecticide granules and recorded as a percentage.

<u>Observation on pod borer (*Polyommatus boeticus* L.) damage</u>:

Fortyfive pods were selected at random from 3 alternate rows in each plot and observed for pod borer infestation on the 40th day after application of insecticide granules and percentage infestation worked out.

<u>Residual toxicity of insecticides to *Aphis craccivora*</u>

The persistent toxicity of the insecticide in cowpea to pea aphid was assessed by confining the aphids on the treated plants and observing the mortality at regular intervals. For this study, the terminal growing point of the individual plants was cut and placed in specimen tubes of size 10 cm x 1 cm (dia.) and 10 aphids were released inside and the mouth was covered with muslin cloth. Mortality was observed after 24 hours and expressed as percentage. Five such assessments were conducted at 10 days' interval starting from 10th day after insecticide granule application.

Effect of insecticides on crop growth and yield:

This was assessed in terms of plant height, number of branches, weight of shoot, weight of root, length of tap root, number of nodules and dry weight of nodules.

Plant height was measured from the soil level to the tip of the growing point on the 50th day after application of the granules.

Number of branches in the plant was also recorded on the 50th day after application of insecticide granules.

Sample plants from the plots under various treatments were uprooted on the 20th day after application of insecticide granules and the weight of shoot, weight of root, length of tap root, number of nodules and dry weight of nodules were determined.

Harvest of the crop:

The ripe pods were harvested by hand-picking on the 58th day of the crop followed by 3 more picking at 4 days' interval. The pods were harvested from each net plot separately during each picking and pods from each net plot were finally pooled together, shelled, cleaned and the seeds weighed. From this, the yield of cowpea in kg per hectare was computed and recorded.

Determination of insecticide residues in cowpea pods.

On the 45th day after application of granules, residue estimation in the long immature green pods under the different treatments, was conducted. Residues were estimated both by colorimetric method and by bioassay technique.

Colorimetric assay of phorate residues in cowpea pods.

The phorate residues in cowpea pods were determined colorimetrically following the method of Getz and Watts (1964) after extracting the residues from pods by employing the acetonitrile hydrocarbon partition technique of Jones and Riddick (1952).

A regression equation was worked out using a standard solution of phorate containing 0, 5, 10, 15 and 25 μg of the insecticide in the untreated cowpea pod extract, and the optical density. The regression equation was

$Y = 0.142x - 0.048$

Extraction of phorate residues in cowpea pods:

Twentyfive grams of cowpea pods were cut into pieces and macerated. This was extracted with 50 ml acetone and filtered over anhydrous sodium sulphate. Evaporated the material to dryness after adding a drop of propylene glycol. The residues were redissolved in 50 ml n-hexane and transferred quantitatively into a 500 ml separating funnel. Equal quantity of saturated acetonitrile was added and shaken for 60 seconds and allowed the layers to separate. The acetonitrile was transferred to another 500 ml separating funnel. The extraction of n-hexane was repeated thrice with 25 ml of acetonitrile and all the acetonitrile fractions were collected in the same 500 ml separating funnel. 250 ml of 4 per cent sodium chloride solution was added, followed by 50 ml n-hexane and the mixture was shaken for 30 seconds. The layers were allowed to separate and the aqueous layer was discarded. The n-hexane layer was then washed thrice with 100 ml each of 4% sodium chloride solution and washings discarded. The n-hexane layer was then filtered over anhydrous sodium sulphate to a 100 ml volumetric flask and volume made up to the mark.

Estimation of phorate residues in cowpea pods:

An aliquot of the hexane extract was taken in B 19/26 test tube for the colour development and the solvent evaporated off after adding a drop of propylene glycol. The colour was developed as described under residue estimation of phorate in the soil. The amount of phorate residue in the extract was determined with reference to the regression equation.

Colorimetric assay of carbofuran residues in cowpea pods.

Carbofuran residues in cowpea pods were determined colorimetrically following the procedure developed by Gupta and Dewan (1973) for estimation of total carbofuran residues.

Standard solutions of carbofuran in methanol containing 100 µg per ml and 40 µg per ml were prepared from a stock solution of 1000 µg per ml. From the stock solution of 40 µg per ml, 0.0, 0.25, 0.5, 1.0, 1.5, 2.0 and 2.5 ml and 1.6 ml of the stock solution containing 100 µg per ml were taken in separate test tubes. The volume was made up to 3 ml using methanol. 7 ml freshly prepared coagulating solution (0.5 gram ammonium chloride mixed with 200 ml glass distilled water and one ml of orthophosphoric acid) was added to each tube and allowed to stand for 10 minutes with occasional shaking. Five ml each of these solutions were pipetted out to separate test tubes and placed in an ice bath. Two ml of 1.5 N methanolic KOH (84.15 gm KOH in 1 litre methanol) was added to the solution, mixed well and allowed to stand for 5 minutes. Then one ml of cold chromogenic reagent (prepared by saturating a cold mixture of 25 mg p-nitrobenzene diazonium tetra fluoborate in 25 ml ethanol and 2 ml glacial acetic acid which was filtered through Whatman No. 42 filter paper and kept below 4°C) was added, shaken well and kept in an ice-bath for two minutes. Then the colour was read at 550 mμ.

The regression equation was then worked out from the absorbance concentration in μg.

$Y = 0.0929x - 0.0452$.

Extraction of carbofuran from the samples:

Acid hydrolysis and solvent extraction: Twentyfive grams each of chopped cowpea pods were taken in 500 ml round bottom flasks and 250 ml 0.25 N hydrochloric acid was added (Cook et al., 1969). Air condensers were fitted and the mixture refluxed in a water bath for two hours. Then the contents were filtered through glass wool over cotton and the volume made up to 250 ml using hot 0.25 N hydrochloric acid and kept overnight for settling.

The extract was transferred to a 500 ml separating funnel and shaken with 45 ml of dichloromethane and 10 drops of 4% solution of sodium lauryl sulphate for 2 minutes. The layer of dichloromethane was drawn out and dried by passing through anhydrous sodium sulphate. This procedure was repeated thrice for each sample and the extracts combined.

The combined extract was then concentrated in a Kuderna-Danish Evaporator and the acetonitrile-hydrocarbon partition technique of Jones and Riddick (1952) as described under colorimetric assay of phorate residues in cowpea pods, was followed to remove the fatty substances from the extract. The volume was then made up to 100 ml with dichloromethane.

Clean up and estimation of the residues:

20 ml aliquot of the dichloromethane extract was shaken with activated charcoal in a test tube and filtered through Whatman No. 1 filter paper. 10 ml of the filtrate was evaporated to almost dryness using a manifold dry air-evaporator. The sides of the test tube was rinsed down with 3 ml methanol and 7 ml freshly prepared coagulating solution was added to it . This was allowed to stand for 10 minutes with occasional shaking and filtered through Whatman No. 42 filter paper. The filtrate was further processed as described already and the colour read at 550 m/u.

Colorimetric assay of disulfoton residues in cowpea pods.

Disulfoton residues in cowpea pods were determined colorimetrically following the procedure developed by Getz and Watts (1964) as modified by Jain et al. (1974).

A regression equation was worked out using a standard solution of disulfoton technical containing 5, 10, 15, 20 and 25 ppm of the insecticide in the untreated cowpea pod extract.

$$Y = 0.114x - 0.00037.$$

Extraction of disulfoton residues in cowpea pods:

Twentyfive grams each of the sample of cowpea pods were extracted with 100 ml of acetone by macerating in a blender for 3 minutes. The macerate was filtered over anhydrous sodium sulphate and the filtrate evaporated in a Kuderna Danish evaporator after adding a drop of propylene glycol. The concentrate was then extracted four times successively with 25 ml lots of chloroform. The chloroform extract was then cleaned by passing it through a column containing 4-5 cm layer of anhydrous sodium sulphate and 5 gm of absorbant mixture (2 : 2 : 1, Charcoal : Celite : Magnesiumoxide). The clean extract was collected in a volumetric flask and made up to 100 ml with chloroform.

Estimation of disulfoton residues in cowpea pods:

A 20 ml aliquot of the chloroform extract was taken, evaporated and concentrated in a Kuderna Danish evaporator after adding a drop of propylene glycol. Then the colour was developed as mentioned under colorimetric estimation of phorate residues.

The quantity of disulfoton residue in the extract was determined with reference to the regression equation.

Bioassay of insecticide residues in cowpea pods.

The residues of phorate, carbofuran and disulfoton in cowpea pods were estimated by bioassay using adults of *Drosophila melanogaster* as the test insect. The extracts which were used for colorimetric estimation were made use of. Mortality observations were taken at the end of 8 hours.

Calculation of the residues:

The quantity of insecticide residues in the extract was calculated by referring to the regression equation which was prepared from 0.4, 0.2, 0.1, 0.05 and 0.025 ppm of technical phorate and disulfoton and 0.25, 0.125, 0.0625, 0.03125, 0.015625 ppm of technical carbofuran.

The regression equations were:

Phorate: $Y = 1.366x + 4.166$

Disulfoton $Y = 1.4522x + 3.4484$

Carbofuran: $Y = 0.6904x + 4.585$

Recovery tests:

The reliability of the different methods adopted for the colorimetric estimation of the residues of phorate, disulfoton and carbofuran in soil and in cowpea pods was assessed by conducting recovery tests. The recovery of the insecticides was done using 5, 10 and 50 μg.

Twentyfive grams of untreated samples of soil and cowpea pods were taken in 50 ml beakers and fortified with 5, 10 and 50 μg of the technical grades of the insecticides and soaked well into the sample using the solvents. After 12 hours, the samples were subjected to extraction, clean-up and estimation followed for the different insecticides as described earlier. The recovered insecticide was estimated referring to their respective regression equations and the percentage recovery calculated. Percentage recovery of different insecticides from soil and cowpea pods is given below.

Table 1. Recovery percentage for different insecticides in soil and cowpea pods

Insecticide	Mean per cent recovery		
	5 ppm	10 ppm	50 ppm
Phorate in soil	92.2	94.5	98.5
Disulfoton in soil	95.3	96.1	97.4
Phorate in cowpea pods	87.0	84.2	90.0
Disulfoton in cowpea pods	85.2	86.3	89.5
Carbofuran in cowpea pods	81.2	83.6	87.2

RESULTS

RESULTS

HORIZONTAL MOVEMENT OF SYSTEMIC INSECTICIDES IN DIFFERENT TYPES OF SOILS

Sandy soil.

The results of observations made on the movement of phorate, carbofuran and disulfoton in sandy soil presented in Table 2 and illustrated in Fig. 2, show three important features. Firstly, it is seen that all the three insecticides moved to a distance of 80 cm from the point of application. The amount of insecticide reaching the different parts, away from the point of application decreased as the distance increased. Thus in the case of phorate, the mean aphid mortalities over 2 doses and 3 occasions of observations were 93.84, 91.66, 67.84, 47.47 and 17.83 at 10, 20, 40, 60 and 80 cm from the point of application respectively. In the case of carbofuran, the mortalities were 91.74, 76.12, 49.11, 22.19 and 13.67 respectively and for disulfoton 86.59, 72.63, 55.15, 23.59 and 10.73 respectively. The effect of distances on the movement of the three insecticides was highly significant (Appendix I). There was also significant difference in the amount of insecticide reaching the different points.

The second feature observed was the effect of amount of the insecticide applied at a point on their movement. It was observed that in general, higher the amount of

Table 2. Percentage mortality of *Aphis craccivora* on cowpea plants in sandy soil planted at different distances from point of application of insecticide granules, observed at different intervals after application.

Insecticide		Phorate			Carbofuran			Disulfoton		
Dose										
Distance (cm)	Interval of insecticide application (days)	High	Low	Mean*	High	Low	Mean*	High	Low	Mean*
10	1	100.00 (90.00)	100.00 (90.00)	100.00	100.00 (90.00)	100.00 (90.00)	100.00	96.92 (79.89)	100.00 (90.00)	98.46
	2	100.00 (90.00)	96.92 (79.89)	98.46	100.00 (90.00)	100.00 (90.00)	100.00	80.00 (63.44)	96.92 (79.89)	88.46
	4	90.96 (72.50)	75.17 (60.11)	83.07	85.36 (67.50)	65.08 (53.78)	75.22	75.17 (60.11)	70.50 (57.10)	72.84
	Mean	96.99	90.70	93.84	95.12	88.36	91.74	84.03	89.14	86.59
20	1	100.00 (90.00)	96.92 (79.89)	98.46	94.00 (75.82)	96.92 (79.89)	95.46	85.36 (67.50)	90.00 (71.56)	87.68
	2	96.92 (79.89)	94.00 (75.82)	95.46	76.74 (61.17)	94.00 (75.82)	85.37	75.17 (60.11)	75.17 (60.11)	75.17
	4	85.36 (67.50)	76.74 (61.17)	81.05	55.25 (48.01)	39.80 (39.11)	47.53	55.03 (47.89)	55.03 (47.89)	55.03
	Mean	94.09	89.22	91.66	75.33	76.91	76.12	71.85	73.40	72.63
40	1	100.00 (90.00)	96.92 (79.89)	98.46	80.00 (63.44)	65.10 (53.79)	72.55	65.10 (53.79)	65.10 (53.79)	65.10
	2	65.80 (54.21)	65.10 (53.79)	65.45	55.03 (47.89)	45.00 (42.13)	50.02	60.20 (50.89)	65.80 (54.21)	63.00
	4	34.20 (35.79)	45.00 (42.13)	39.60	29.50 (32.90)	20.00 (26.56)	24.75	39.80 (39.11)	34.90 (36.21)	37.35
	Mean	66.67	69.01	67.84	54.84	43.37	49.11	55.03	55.27	55.15
60	1	80.00 (63.44)	75.17 (60.11)	77.59	29.50 (32.90)	29.50 (32.90)	29.50	29.50 (32.90)	30.00 (33.21)	29.75
	2	45.00 (42.13)	39.80 (39.11)	42.40	20.00 (26.56)	24.83 (29.89)	22.42	18.97 (25.82)	34.90 (36.21)	26.94
	4	24.83 (29.89)	20.00 (26.56)	32.42	14.64 (22.50)	14.64 (22.50)	14.64	8.17 (16.61)	20.00 (26.56)	14.09
	Mean	49.94	44.99	47.47	21.38	22.99	22.19	18.88	28.30	23.59
80	1	34.90 (36.21)	34.90 (36.21)	34.90	20.00 (26.56)	24.83 (29.89)	22.42	20.00 (26.57)	14.64 (22.50)	17.32
	2	14.64 (22.50)	10.00 (18.44)	13.32	20.00 (26.56)	14.64 (22.50)	17.32	14.64 (22.50)	10.00 (18.44)	12.32
	4	2.55 (9.22)	10.00 (18.44)	6.28	2.55 (9.22)	0.00 (0.00)	1.28	2.55 (9.22)	2.55 (9.22)	2.55
	Mean	17.36	18.30	17.83	14.18	13.16	13.67	12.40	9.06	10.73

* Values are mean of 2 doses.

Angular values in parenthesis.

insecticide applied at a point, higher was the quantity of insecticide reaching the different points. This was observed to be so for all the three insecticides and at all the five distances away from the point of application. The differences were, however, not statistically significant.

The third feature observed was the effect of period elapsing after the application of insecticides on their movement. The data presented show that on the 1st, 2nd and 4th day after application, there was a corresponding reduction in aphid mortality indicating a decrease in the insecticide reaching the points on different occasions. This trend was observed with all the 3 insecticides at all the distances. The results of analysis have shown that the decrease in the mortality at the different points observed at different occasions was highly significant.

Among the 3 insecticides, observations on the aphid mortality caused by the 3 insecticides at 1 kg ai per hectare showed that the movement of phorate was significantly more than that of the other 2 insecticides. Carbofuran and disulfoton were on par in these respects. This relative position was found to exist at all distances except 10 cm. At 10 cm, the mean mortality at 1 kg ai per hectare was 90.70 for phorate, 95.12 for carbofuran and 89.14 for disulfoton. At 20 cm, these were 89.22, 75.33 and 73.40

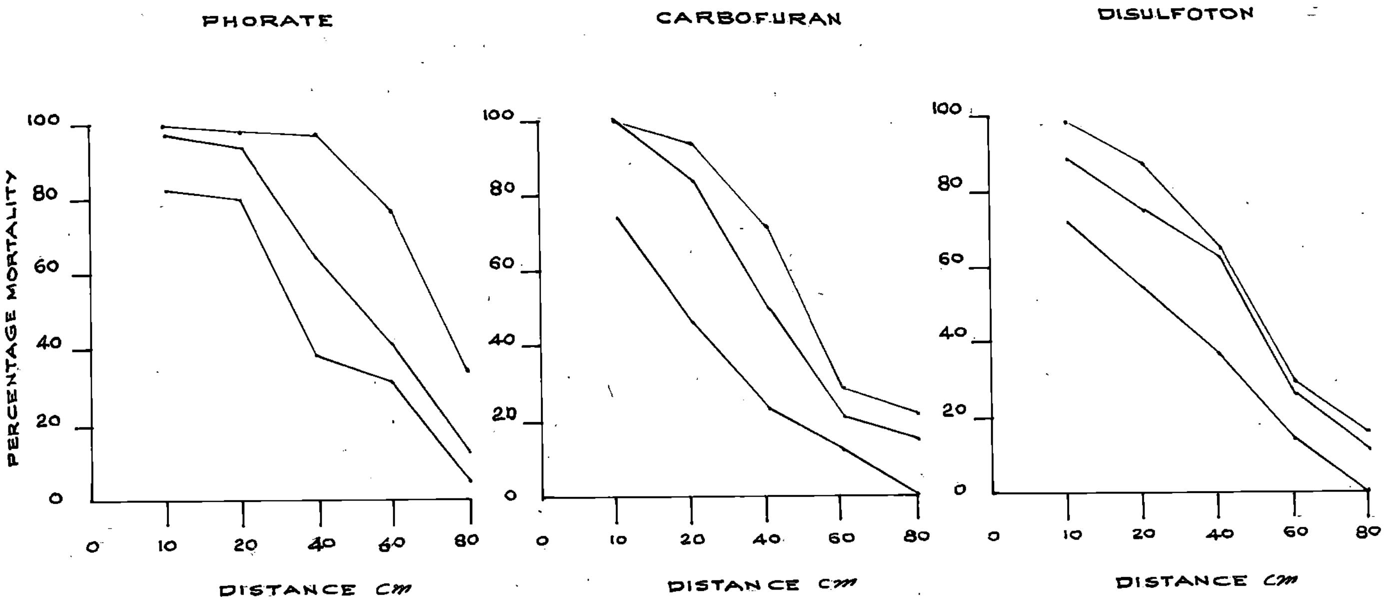
Fig. 2-3 Percentage mortality of aphids on cowpea in relation to horizontal movement of systemic insecticides in different types of soil.

Fig. 2 Percentage mortality of aphids on cowpea at 10, 20, 40, 60 and 80 cm on the 1st, 2nd and 4th day after application of systemic granular insecticides in sandy soil.

Fig. 3 Percentage mortality of aphids on cowpea at 10, 20, 40, 60 and 80 cm on the 1st, 2nd and 4th day after application of systemic granular insecticides in alluvial soil.

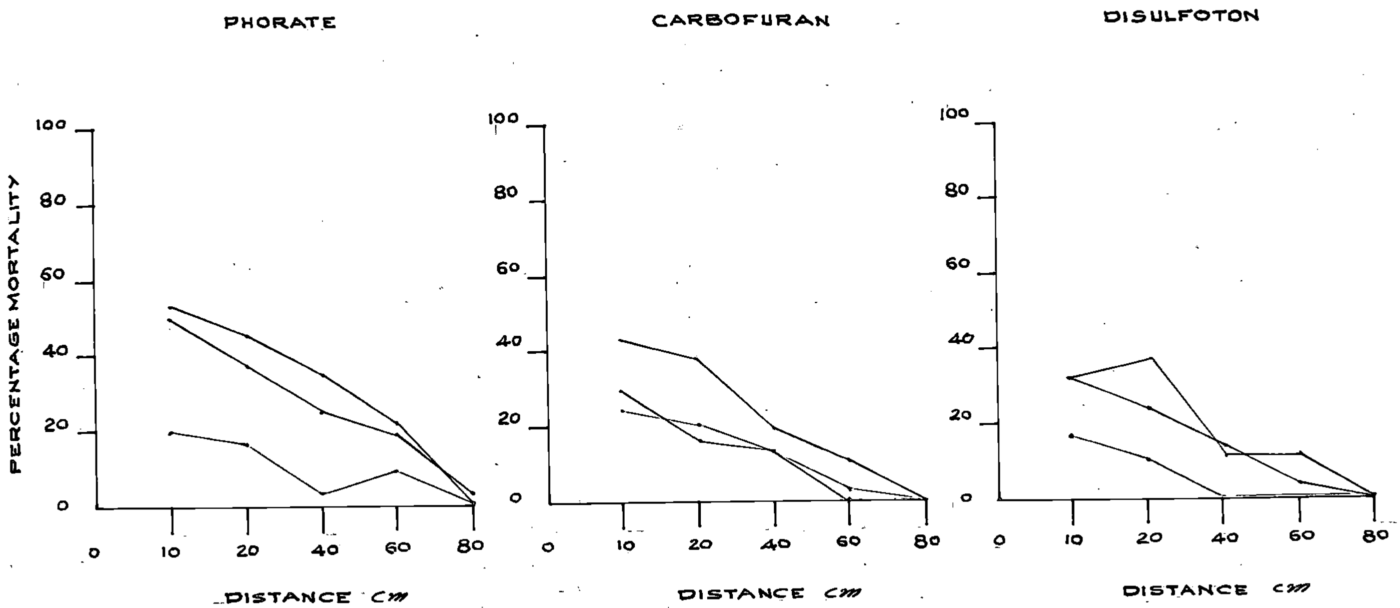
PERCENTAGE MORTALITY OF APHIDS ON COWPEA IN RELATION TO HORIZONTAL MOVEMENT OF SYSTEMIC INSECTICIDES.

FIG. 2. SANDY SOIL



1st DAY AFTER APPLICATION — 2nd DAY AFTER APPLICATION — 4th DAY AFTER APPLICATION

FIG. 3. ALLUVIAL SOIL



respectively. At 40 cm, the mortalities were 69.01, 54.84 and 55.27 and at 60 cm, 44.99, 21.38 and 28.3 and at 80 cm, 18.30, 14.18 and 9.06 respectively for the 3 insecticides.

Alluvial soil

The results presented in Table 3 and illustrated in Fig. 3, show that all the 3 insecticides moved up to a distance of 60 cm but phorate showed a significantly low aphid mortality of 1.28 at 60 cm. The quantity of insecticide reaching the different points away from the point of application decreased as the distance increased. Phorate granules gave a mean aphid mortality of 40.95, 33.50, 21.18 and 17.10 at 10, 20, 40, and 60 cm respectively. In the case of carbofuran the mean aphid mortality was 32.52, 25.18, 16.34 and 5.27 at 10, 20, 40 and 60 cm respectively whereas disulfoton application resulted in a mean aphid mortality of 27.38, 24.32, 14.48 and 4.91 at 10, 20, 40 and 60 cm respectively. The effect of distance on the mortality and thus movement of the three insecticides was highly significant (Appendix II). The difference in aphid mortalities at the different distances indicated the different amount of insecticides reaching the different points.

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The effect of amount of the insecticides applied at a point on their movement revealed that higher dose of the insecticides in general resulted in significantly greater mortality of aphids than the lower doses.

As regards the effect of period elapsing after the application of insecticides on their movements, maximum mortality of aphids indicating maximum movement of the insecticides was observed on the second day of application of insecticides and it was significantly greater than movement on the 4 th day after application. Movement of insecticides in alluvial soil was slow on the 1st day of application and was significantly lesser than movement on the succeeding days. This trend was observed with all the three insecticides at all the distances.

Observation of aphid mortality caused by the 3 insecticides showed that maximum movement was for phorate and it was significantly greater than that of carbofuran which in turn was significantly greater than that of disulfoton. Observation of aphid mortality due to application of the 3 insecticides at 1 kg per hectare showed that movement of phorate was more than those of carbofuran and disulfoton in this soil. At 10 cm, mean aphid mortalities due to phorate, carbofuran and

Table 3. Percentage mortality of *Aphis craccivora* on cowpea plants in alluvial soil planted at different distances from point of application of insecticide granules, observed at different intervals after application.

Insecticide		Phorate			Carbofuran			Disulfoton		
Dose										
Distance (cm)	Interval of observation of mortality (days)	High	Low	Mean	High	Low	Mean	High	Low	Mean
10	1	15.80 (25.42)	24.83 (29.89)	20.32	24.83 (29.89)	24.83 (29.89)	24.83	20.00 (26.56)	14.64 (22.50)	17.32
	2	55.03 (47.89)	50.00 (45.00)	52.52	50.00 (45.00)	35.30 (36.45)	42.65	40.00 (39.23)	24.83 (29.89)	32.42
	4	50.00 (45.00)	50.00 (45.00)	50.00	35.30 (36.45)	24.83 (29.89)	30.07	40.00 (39.23)	24.83 (29.89)	32.42
	Mean	40.28	41.61	40.95	36.71	28.32	32.52	33.33	21.43	27.38
20	1	18.97 (25.82)	14.64 (22.50)	16.81	20.00 (26.56)	20.00 (26.56)	20.00	20.00 (26.56)	2.55 (9.22)	11.28
	2	45.00 (42.13)	45.00 (42.13)	45.00	40.00 (39.23)	36.46 (37.15)	38.23	40.00 (39.23)	34.90 (36.21)	37.45
	4	42.50 (40.69)	34.90 (36.21)	38.70	20.00 (26.56)	14.64 (22.50)	17.32	33.85 (35.64)	14.64 (22.50)	24.25
	Mean	34.49	31.51	33.50	26.67	23.70	25.18	31.28	17.36	24.32
40	1	2.55 (9.22)	2.55 (9.22)	2.55	14.64 (22.50)	14.64 (22.50)	14.64	0.00 (0.00)	0.00 (0.00)	0.00
	2	40.00 (39.23)	30.00 (33.21)	35.00	14.64 (22.50)	24.83 (29.89)	19.74	10.00 (18.44)	23.26 (28.83)	11.63
	4	37.35 (37.67)	14.64 (22.50)	26.00	14.64 (22.50)	14.64 (22.50)	14.64	14.64 (22.50)	10.00 (18.44)	12.32
	Mean	26.63	15.73	21.18	14.64	18.04	16.34	12.32	16.63	14.48
60	1	18.97 (25.82)	0.00 (0.00)	9.49	2.55 (9.22)	2.55 (9.22)	2.55	0.00 (0.00)	0.00 (0.00)	0.00
	2	29.50 (32.90)	14.64 (22.50)	22.07	14.64 (22.50)	5.38 (13.29)	10.01	2.55 (9.22)	18.97 (25.82)	10.76
	4	24.83 (29.89)	14.64 (22.50)	19.74	2.55 (9.22)	0.00 (0.00)	1.28	5.38 (13.29)	2.55 (9.22)	3.97
	Mean	24.43	9.76	17.10	6.58	3.97	5.27	2.64	7.17	4.91
80	1	0.00 (0.00)	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00
	2	2.55 (9.22)	0.00 (0.00)	1.28	0.00 (0.00)	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00
	4	2.55 (9.22)	2.55 (9.22)	2.55	0.00 (0.00)	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00
	Mean	1.70	0.85	1.28	0.00	0.00	0.00	0.00	0.00	0.00

Angular values in parenthesis.

disulfoton were 41.61, 36.71 and 21.43 respectively while at 20 cm, the mortalities were 31.51, 26.67 and 17.36 respectively. At 40 cm, the mortalities were 15.75, 14.64 and 16.65 respectively while at 60 cm, the mortalities were 9.76, 6.58 and 7.17 respectively for the 3 insecticides.

Red soil.

The data on the movement of phorate, carbofuran and disulfoton in red soil is presented in Table 4 and Fig. 4, with their statistical analysis in Appendix III.

It was observed that there was aphid mortality at the furthest distance at 80 cm indicating that all the three insecticides moved up to 80 cm in red soil. Phorate at 2 doses and over 3 intervals of observation recorded a mean aphid mortality of 79.13, 64.29, 47.84, 28.63 and 6.43 at 10, 20, 40, 60 and 80 cm respectively. In the case of carbofuran, the mean aphid mortalities were 61.13, 53.10, 40.51, 23.88 and 6.97 at 10, 20, 40, 60 and 80 cm respectively. Disulfoton effected mean aphid mortalities of 63.05, 55.95, 39.09, 21.28 and 7.05 at 10, 20, 40, 60 and 80 cm respectively. The effect of distance on the movement of the insecticides was highly significant.

Table 4. Percentage mortality of Aphis craccivora adults on cowpea plants in red soil, planted at different distances from point of application of insecticide granules observed at different intervals after application.

Insecticide		Phorate			Carbofuran			Disulfoton		
Dose										
Distance (cm)	Interval of insecticide application (days)	High	Low	Mean	High	Low	Mean	High	Low	Mean
10	1	100.00 (90.00)	100.00 (90.00)	100.00	96.92 (79.89)	100.00 (90.00)	98.46	100.00 (90.00)	100.00 (90.00)	100.00
	2	96.92 (79.89)	65.10 (53.79)	81.01	60.00 (50.77)	45.00 (42.13)	52.50	65.10 (53.79)	50.00 (45.00)	52.55
	4	67.73 (55.39)	45.00 (42.13)	56.37	40.00 (39.23)	24.83 (29.89)	32.42	44.75 (41.99)	28.47 (31.61)	36.61
	Mean	88.22	70.03	79.13	65.64	56.61	61.13	69.95	59.49	63.05
20	1	96.92 (79.89)	80.00 (63.44)	88.46	60.96 (51.33)	80.00 (63.44)	70.48	96.92 (79.89)	85.36 (67.50)	91.14
	2	94.00 (75.82)	45.00 (42.13)	69.50	62.60 (52.30)	55.03 (47.89)	58.82	50.00 (45.00)	40.00 (39.23)	45.00
	4	39.80 (39.11)	30.00 (33.21)	34.90	30.00 (33.21)	30.00 (33.21)	30.00	34.90 (36.21)	28.47 (31.61)	31.69
	Mean	76.91	51.67	64,29	51.19	55.01	53.10	60.61	51.28	55.95
40	1	75.17 (60.11)	70.00 (56.79)	72.59	65.10 (53.79)	59.35 (50.39)	62.23	70.00 (56.79)	55.03 (47.89)	62.52
	2	50.00 (45.00)	28.47 (31.61)	39.24	40.00 (39.23)	30.00 (33.21)	35.00	40.00 (39.23)	34.90 (36.21)	37.45
	4	34.90 (36.21)	28.47 (31.61)	31.69	20.00 (26.57)	28.47 (31.61)	24.24	20.00 (26.56)	14.64 (22.50)	17.32
	Mean	53.36	42.31	47.84	41.70	39.32	40.51	43.33	34.86	39.09
60	1	55.03 (47.89)	35.30 (36.44)	45.17	28.47 (31.61)	35.30 (36.44)	31.89	34.90 (36.21)	28.47 (31.61)	31.69
	2	30.00 (33.21)	20.00 (26.56)	25.00	30.00 (33.21)	24.83 (29.89)	27.42	16.83 (24.22)	34.90 (36.21)	25.87
	4	16.83 (24.22)	14.64 (22.50)	15.74	14.64 (22.50)	10.00 (18.44)	12.32	10.00 (18.44)	2.55 (9.22)	6.28
	Mean	33.95	23.31	28.63	24.37	23.38	23.88	20.58	21.97	21.28
80	1	14.64 (22.50)	10.00 (18.44)	12.32	14.64 (22.50)	10.00 (18.44)	12.32	14.64 (22.50)	10.00 (18.44)	12.32
	2	2.55 (9.22)	2.55 (9.22)	2.55	14.64 (22.50)	2.55 (9.22)	8.60	10.00 (18.44)	2.55 (9.22)	6.28
	4	2.55 (9.22)	0.00 (0.00)	1.28	0.00 (0.00)	0.00 (0.00)	0.00	2.55 (9.22)	2.55 (9.22)	2.55
	Mean	6.58	6.28	6.43	9.76	4.18	6.97	9.06	5.03	7.05

Angular values in parenthesis.

Maximum mortality of aphids was observed in the plants grown at 10 cm distance and as the distance increased the mortalities decreased significantly for all the three insecticides.

Regarding the effect of amount of insecticide applied at a point on their movement, it was noted that the higher doses of insecticides in general, when applied at a point caused significantly higher aphid mortality than the lower doses.

Another finding was the effect of period (intervals) passing by after the application of insecticides, on the mortality of aphids at each distance from the point of application. The data presented in Table 4 show that as the intervals increased from 1st day to 2nd day and further to the 4th day after application, there was a reduction in aphid mortality for all the 3 insecticides over the 5 distances. Statistical analysis confirmed that mortality decreased significantly at the different points as the period (interval) of observations after insecticide application increased.

Statistical analysis showed that movement in soil and uptake of phorate by cowpea plants as judged by aphid mortality was significantly greater than disulfoton and

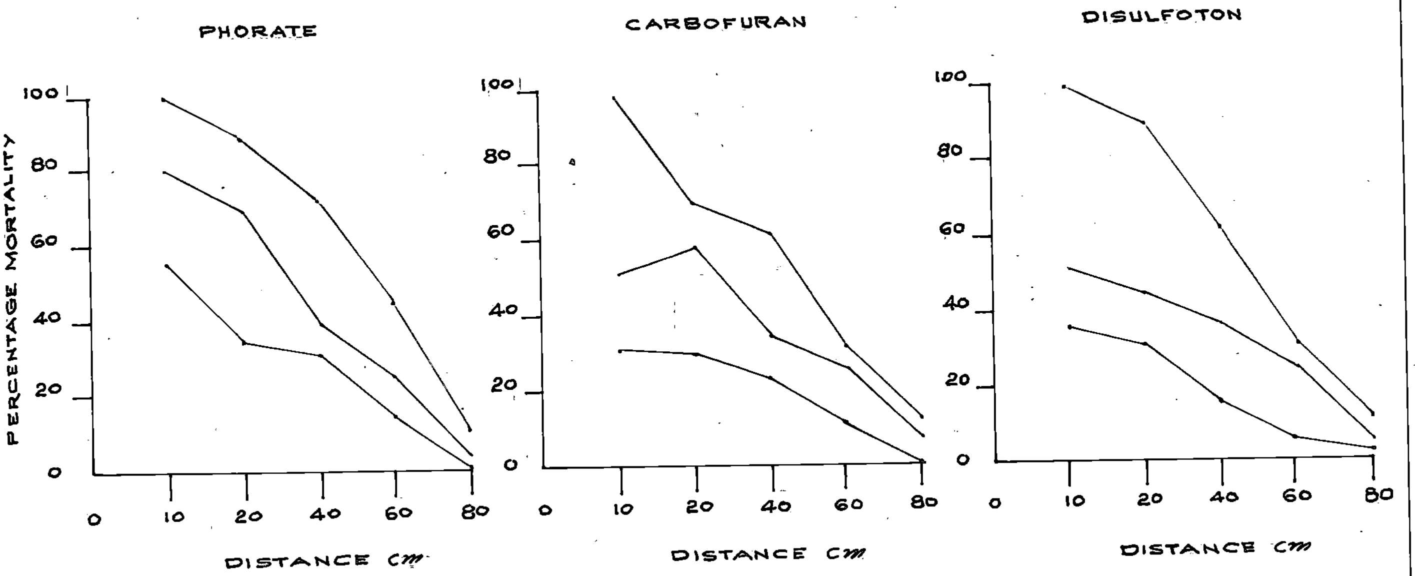
Fig. 4-5 Percentage mortality of aphids on cowpea in relation to horizontal movement of systemic insecticides in different types of soil.

Fig. 4 Percentage mortality of aphids on cowpea at 10, 20, 40, 60, and 80 cm on the 1st, 2nd and 4th day after application of systemic granular insecticides in red soil.

Fig. 5 Percentage mortality of aphids on cowpea at 10, 20, 40, 60 and 80 cm on the 1st, 2nd and 4th day after application of systemic granular insecticides in laterite soil.

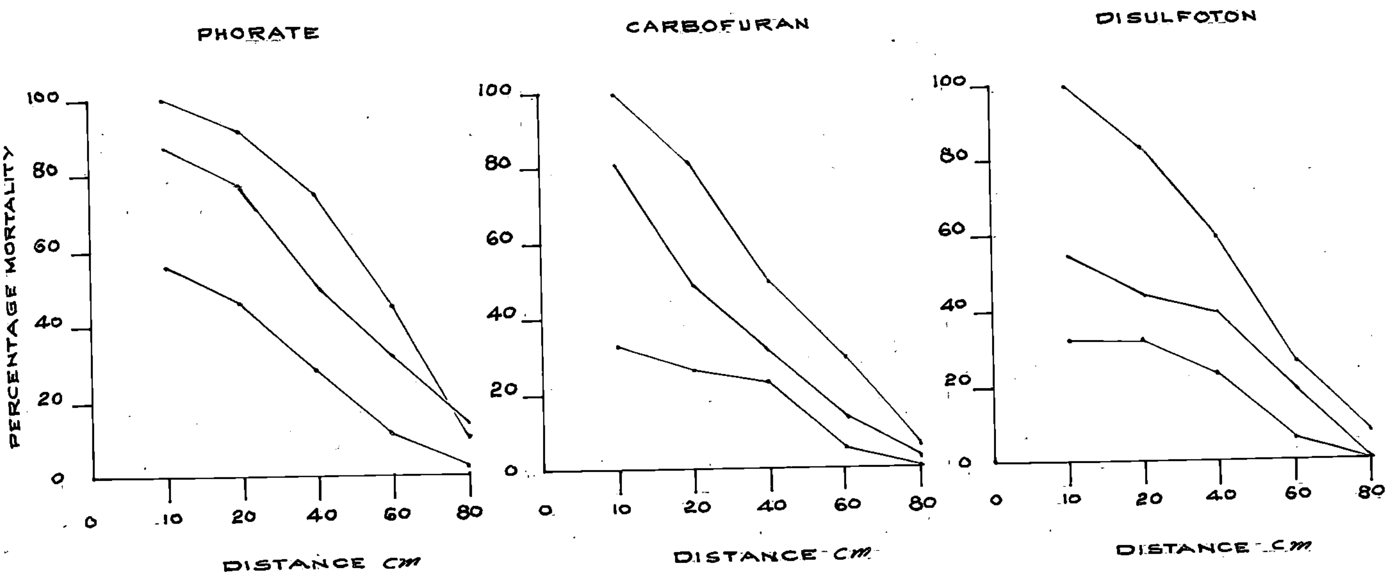
PERCENTAGE MORTALITY OF APHIDS ON COW PEA IN RELATION TO HORIZONTAL MOVEMENT OF SYSTEMIC INSECTICIDES.

FIG. 4. RED SOIL



1st DAY AFTER APPLICATION — 2nd DAY AFTER APPLICATION — 4th DAY AFTER APPLICATION

FIG. 5. LATERITE SOIL



carbofuran which were statistically on par (Appendix III). Data on the aphid mortality caused by the 3 insecticides at 1 kg ai per hectare revealed that except at 10 cm distance, movement of the 3 insecticides was on par. At 10 cm, the mean aphid mortality was 70.03 for phorate, 65.64 for carbofuran and 59.49 for disulfoton. At 20 cm, the values were 51.67, 51.19 and 51.28 respectively. At 40 cm, the mortalities were 42.31, 41.70 and 34.86 and at 60 cm, 23.31, 24.37 and 21.97 respectively. At 80 cm, the mean mortalities were 6.28, 9.76 and 5.03 respectively for phorate, carbofuran and disulfoton.

Laterite soil

The data on the movement of phorate, carbofuran and disulfoton in laterite soil is presented in Table 5 and Fig. 5. The results of statistical analysis is given in Appendix IV.

Aphid mortality due to insecticide application, observed at different distances indicated that the insecticides moved up to 80 cm in laterite soil. Phorate at 2 doses and over 3 intervals of observation recorded mean aphid mortalities of 82.24, 72.62, 52.58, 28.26 and 5.97 at 10, 20, 40, 60 and 80 cm respectively. Carbofuran treatment resulted in mean aphid mortalities of 72.49, 53.48, 35.72, 16.78 and 2.94 at 10, 20, 40, 60 and 80 cm respectively while disulfoton accounted for mean mortalities of 64.14, 54.89, 41.50, 18.33 and 3.29 over the 5 distances respectively. The effect of distance on the movement of the insecticide was highly significant. Maximum mortality of aphids was observed at the closest distance of 10 cm and mortality decreased significantly as the distance increased for all the three insecticides.

Regarding the effect of quantity of insecticides applied at a point on their movement, it was observed that the higher doses of insecticides caused significantly higher mortality of aphids than the lower doses. This was noted at all the five distances.

The effect of period (interval) elapsing after the application of insecticides, on the aphid mortality at each distance from the point of application showed that at all the distances, maximum mortality was noted on the 1st day after application of phorate, carbofuran and disulfoton and it was significantly greater than mortality on the 2nd day of application which in turn was significantly greater than mortality on the 4th day of application of the insecticide granules.

Table 5. Percentage mortality of *Aphis craccivora* adults on cow pea plants in laterite soil planted at different distances from point of application of insecticide granules, observed at different intervals after application.

Insecticide		Phorate			Carbofuran			Disulfoton		
Dose										
Distance (cm)	Interval of observation of mortality. (days)	High	Low	Mean	High	Low	Mean	High	Low	Mean
10	1	100.00 (90.00)	100.00 (90.00)	100.00	100.00 (90.00)	100.00 (90.00)	100.00	100.00 (90.00)	100.00 (90.00)	100.00
	2	96.92 (79.89)	81.03 (64.18)	88.98	65.80 (54.21)	100.00 (90.00)	82.90	65.10 (53.79)	45.00 (42.13)	55.05
	4	70.50 (57.10)	45.00 (42.13)	57.75	34.20 (35.79)	34.90 (36.21)	34.55	44.75 (41.99)	30.00 (33.21)	33.38
	Mean	89.14	75.34	82.24	66.67	78.30	72.49	69.95	58.33	64.14
20	1	100.00 (90.00)	85.36 (67.50)	92.68	76.74 (61.17)	90.00 (71.57)	83.37	94.00 (75.82)	75.17 (60.11)	84.59
	2	85.36 (67.50)	70.00 (56.79)	77.68	44.75 (41.99)	55.03 (47.89)	49.89	55.03 (47.89)	35.30 (36.45)	45.17
	4	50.00 (45.00)	45.00 (42.13)	47.50	29.50 (32.90)	24.83 (29.89)	27.17	45.00 (42.13)	24.83 (29.89)	34.92
	Mean	78.45	66.79	72.62	50.33	56.62	53.48	64.68	45.10	54.89
40	1	85.36 (67.50)	65.10 (53.79)	75.23	55.23 (48.01)	45.00 (42.13)	50.12	65.10 (53.79)	55.03 (47.89)	60.07
	2	60.00 (50.77)	45.00 (42.13)	52.50	34.90 (36.21)	29.50 (32.90)	32.20	45.00 (42.13)	34.90 (36.21)	39.95
	4	30.00 (33.21)	30.00 (33.21)	30.00	24.83 (29.89)	24.83 (29.89)	24.83	34.90 (36.21)	14.64 (22.50)	24.77
	Mean	58.45	46.70	52.58	38.32	33.11	35.72	48.33	34.86	41.59
60	1	50.00 (45.00)	40.10 (39.29)	45.05	29.50 (32.90)	29.50 (32.90)	29.50	35.30 (36.45)	20.00 (26.56)	27.65
	2	30.00 (33.21)	24.83 (29.89)	32.42	14.64 (22.50)	14.64 (22.50)	14.64	30.00 (33.21)	10.00 (18.44)	20.00
	4	14.64 (22.50)	10.00 (18.44)	12.32	10.00 (18.44)	2.55 (9.22)	6.28	14.64 (22.50)	0.00 (0.00)	7.32
	Mean	31.55	24.98	28.26	18.05	15.56	16.78	26.65	10.00	18.33
80	1	16.85 (24.22)	2.55 (9.22)	9.69	2.55 (9.22)	10.00 (18.44)	6.28	14.64 (22.50)	2.55 (9.22)	8.60
	2	14.64 (22.50)	14.64 (22.50)	14.64	2.55 (9.22)	2.55 (9.22)	2.55	2.55 (9.22)	0.00 (0.00)	1.28
	4	2.55 (9.22)	2.55 (9.22)	2.55	0.00 (0.00)	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00
	Mean	11.34	6.58	8.97	1.70	4.18	2.94	5.73	0.85	3.29

Angular values in parenthesis.

Statistical analysis also indicated that phorate showed the maximum movement in soil and it was significantly greater than carbofuran and disulfoton which were statistically on par (Appendix IV). Among the three insecticides, observations of aphid mortality caused by the insecticides at 1 kg ai per hectare showed that movement of phorate in laterite soil was more than carbofuran which in turn was greater than disulfoton. This relative position was found to exist at all the distances. At 10 cm distance, phorate, carbofuran and disulfoton caused mean aphid mortalities of 75.34, 66.67 and 58.33 respectively. At 20 cm, the mortalities were 66.79, 50.33 and 45.10 respectively and at 40 cm, the mortalities were 46.70, 38.32 and 34.86 respectively. At 60 cm, the mortalities were 24.98, 18.05 and 10.00 respectively and at the furthest distance of 80 cm, the mortalities were 6.58, 1.70 and 0.85 for phorate, carbofuran and disulfoton respectively.

MOVEMENT AND UPTAKE OF PHORATE BY 10, 20 AND 40 DAY OLD COWPEA PLANTS GROWN IN RED SOIL

Horizontal movement of phorate in red soil and uptake of the insecticide by cow pea plants was assessed by applying the insecticide at a point in the soil and growing 10,20 and 40 day old plants at distances of 20, 40, 60 and 80 cm. Mortality observations were made after the release of aphid on the plants at different occasions of 1st, 2nd and 4th day after application of the insecticide. The results are presented in Table 6 and Figs. 6, 7 and 8 with the statistical analysis in Appendix V. It was observed that the amount of phorate reaching the plants as indicated by the mortality of aphids decreased as the distance increased from the point of application of phorate. In 10 day old plants, mean aphid mortalities were 63.19, 47.72, 28.57 and 5.38 at 20, 40, 60 and 80 cm respectively. In 20 day old plants, mean mortalities were 73.43, 36.64, 27.03 and 18.12 at 20, 40, 60 and 80 cm respectively while in 40 day old plants, mortalities were 59.80, 43.39, 34.05 and 23.91 at 20, 40, 60 and 80 cm respectively. The effect of distances on the movement of phorate was significant (Appendix V). There was also significant difference in the quantity of insecticide reaching the different distances.

Fig. 6-8 Movement and uptake of phorate by 10, 20 and 40 day old plants grown in red soil

Fig. 6 Movement and uptake of phorate as judged by aphid mortality on 10, 20 and 40 day old cowpea plants at 20, 40, 60 and 80 cm distances on the 1st day after granule application.

Fig. 7 Movement and uptake of phorate as judged by aphid mortality on 10, 20 and 40 day old cowpea plants at 20, 40, 60 and 80 cm distances on the 2nd day after granule application.

Fig. 8 Movement and uptake of phorate as judged by aphid mortality on 10, 20 and 40 day old cowpea plants at 20, 40, 60 and 80 cm distances on the 4th day after granule application

UPTAKE OF PHORATE BY COW PEA PLANTS OF DIFFERENT AGES.

FIG. 6. 1st DAY AFTER APPLICATION

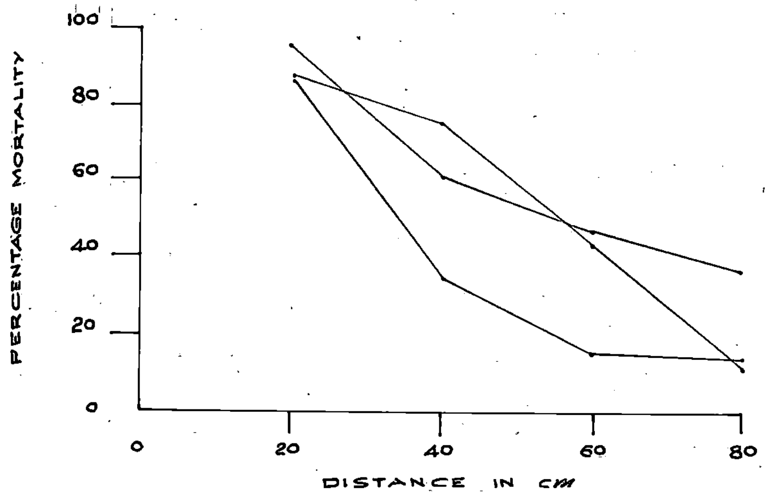


FIG. 7. 2nd DAY AFTER APPLICATION

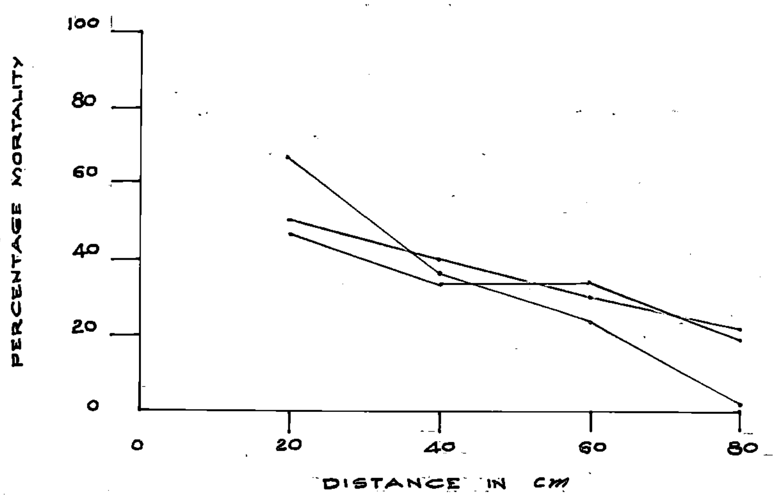
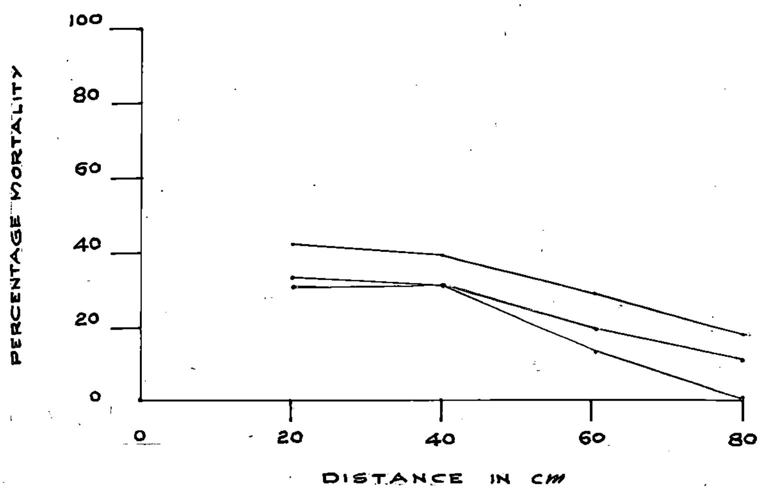


FIG. 8. 4th DAY AFTER APPLICATION



10 DAY OLD PLANTS — 20 DAY OLD PLANTS — 40 DAY OLD PLANTS

Another feature observed was the difference in uptake of phorate applied at a point by 10, 20 and 40 day old plants. At 20 cm, percentage mortality was 63.19, 73.43 and 59.80 for 10 day, 20 day and 40 day old plants respectively while at 40 cm, mortality was 47.72, 36.64 and 43.39 for 10, 20 and 40 day old plants respectively. At 60 cm, mortality was 28.57, 27.03 and 34.05 for 10, 20 and 40 day old plants respectively whereas it was 5.38, 18.12 and 23.91 at 80 cm for 10, 20 and 40 day old plants respectively. Statistical analysis (Appendix V) revealed that uptake of phorate was maximum in 40 day old plants but it was on par with 20 day old plants and significantly greater than 10 day old plants. Mortality in 20 day old and 10 day old plants was statistically on par.

Another feature was the effect of periods (intervals) elapsing after the application of phorate on aphid mortality and thus its movement. Data presented showed that as the days increased after application of phorate, there was corresponding reduction in aphid mortality. Statistical analysis showed that maximum quantity was absorbed by cowpea in the 1st day of application of phorate granules and it was significantly greater than the quantity absorbed on the 2nd day and 4th day after application.

The higher dose of 2 kg ai per hectare of phorate when applied in soil gave a significantly higher aphid mortality on cowpea plants compared to the lower dose of 1 kg ai per hectare.

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Table 6 Percentage mortality of *Aphis craccivora* adults exposed on 10, 20 and 40 day old cowpea plants grown at different distances from point of application of phorate after different intervals in red soil

Distance (cm)		20	40	60	80
Age of plant (days)	Interval of observation of mortality (days)	Mean value of high and low doses	Mean value of high and low doses	Mean value of high and low doses	Mean value of high and low doses
10	1	88.46	75.59	44.97	12.32
	2	67.00	38.74	25.00	2.55
	4	34.10	31.84	15.74	1.28
	Mean	63.19	47.72	28.57	5.38
20	1	87.68	35.01	16.08	14.64
	2	47.50	34.90	35.00	20.00
	4	42.50	40.00	30.00	19.74
	Mean	73.43	36.64	27.03	18.12
40	1	96.92	62.65	47.52	37.50
	2	50.02	40.00	32.20	21.90
	4	32.45	32.45	22.42	12.32
	Mean	59.80	43.39	34.05	23.91

High dose : 2 kg ai per hectare of phorate
Low dose : 1 kg ai per hectare of phorate

VERTICAL MOVEMENT OF PHORATE AND DISULFOTON IN RED SOIL

Data on these studies are presented in Tables 7 and 8 and illustrated in Figs. 9 and 10. Appendix VI gives the analysis of the data.

Results presented in Table 7 showed that phorate when applied at a point in soil left residues of 140.72, 143.3 and 94.28 ppm at a depth of 5-10 cm on the 1st, 3rd and 7th day respectively. At 10-20 cm depth, the residues were 36.98, 28.45 and 30.53 ppm and at 20-30 cm depth, 0.32, 0.07 and 0.00 ppm respectively. Thus it was seen that the residues of the insecticides showed a drastic and significant reduction as the depth of the soil increased. At a depth of 20 cm, the residues were insignificant. There was also a significant decrease in the residues as time passed from 1 to 7 days. This reduction was found at all depths. When phorate was applied broadcast, the residues in the top region of 5-10 cm was significantly lesser (very low) compared to the residues of point application. It varied from 2.18 to 2.7, 0 to 1.07 and 0 to 0.12 ppm under the 3 depth zones during the period of 3 days of observation.

Similar pattern of distribution of residues in relation to depth of soil could be observed with disulfoton

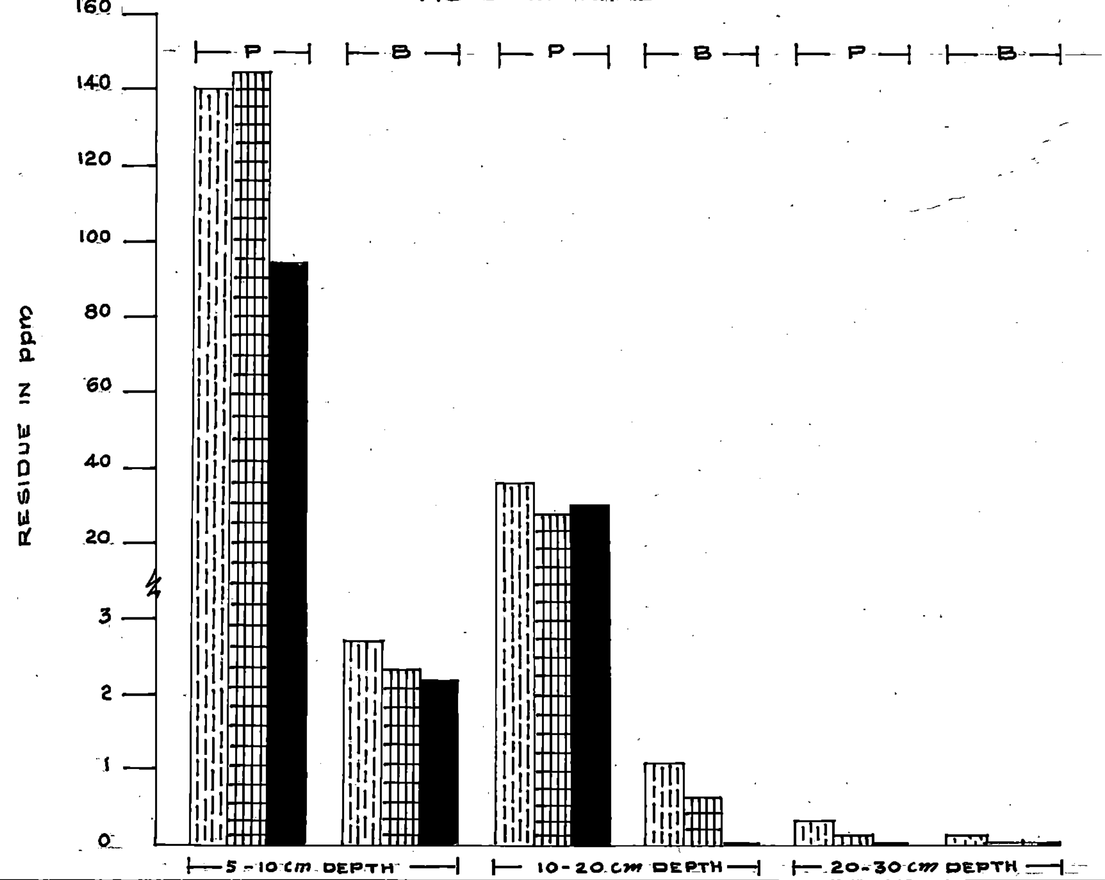
Fig. 9-10 Vertical movement of phorate and disulfoton as estimated by insecticide residues under two different methods of application in red soil.

Fig. 9 Insecticide residues at 3 different depths on the 1st, 3rd and 7th day after point and broadcast applications of phorate granules.

Fig. 10 Insecticide residues at 3 different depths on the 1st, 3rd and 7th day after point and broadcast applications of disulfoton granules.

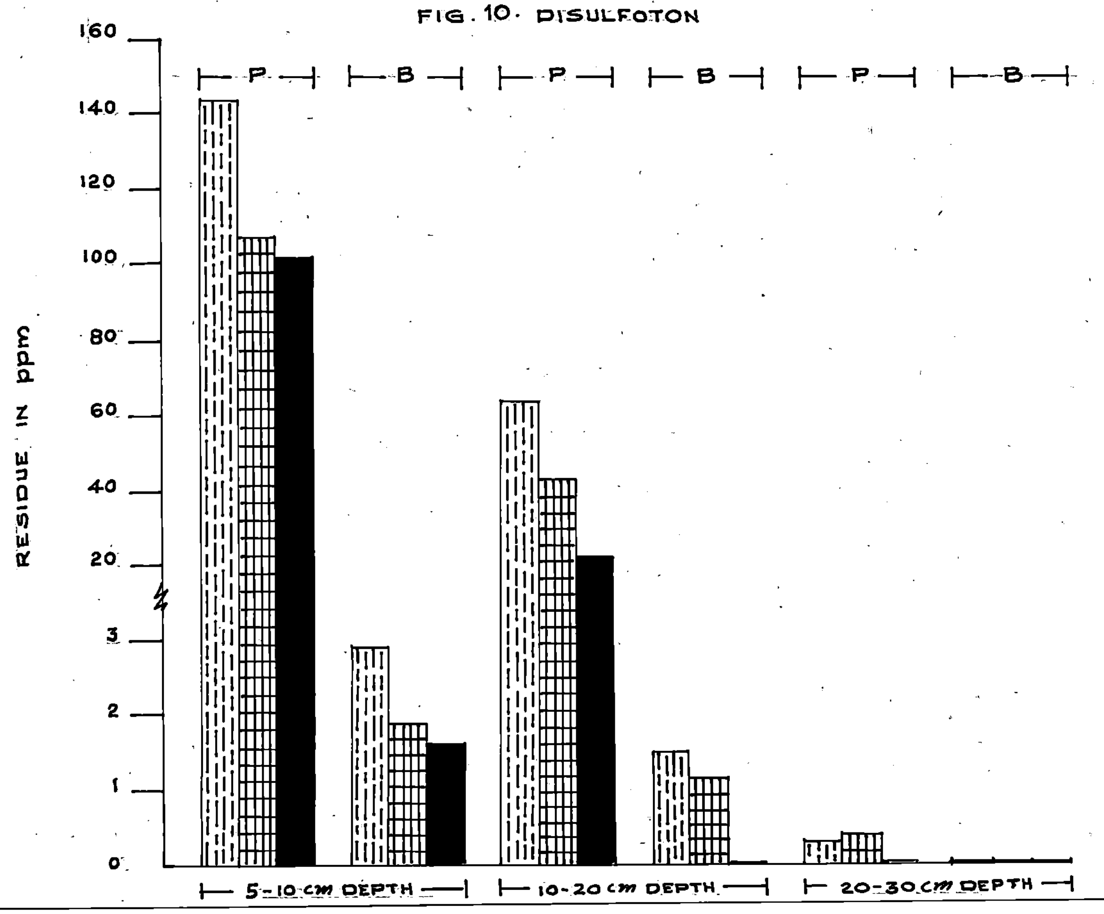
INSECTICIDE RESIDUES AT DIFFERENT DEPTHS UNDER TWO DIFFERENT METHODS OF APPLICATION IN RED SOIL

FIG. 9. PHORATE



1st DAY AFTER APPLICATION
3rd DAY AFTER APPLICATION
7th DAY AFTER APPLICATION
P - POINT APPLICATION ; B - BROADCAST APPLICATION

FIG. 10. DISULFOTON



also. The residues were drastically reduced from 143.69 to 0.35 ppm in one day of application at increasing depths. A reduction in residues of disulfoton was also observed from the 1st to 7th day of application. The residues left after broadcast application were significantly less than those left after point application. The level of residues reaching the 20-30 cm depth was practically nil.

Statistical analysis revealed that vertical movement of phorate and disulfoton in general were statistically on par. Another finding was that there was no significant difference between the quantities of insecticides estimated by bioassay and colorimetry.

Table 7: Colorimetric values (ppm) of quantities of phorate and disulfoton residues at different depths at different intervals after point and broadcast application

Application	Point application						Broadcast application					
Insecticide	Phorate			Disulfoton			Phorate			Disulfoton		
Period (days)	1	3	7	1	3	7	1	3	7	1	3	7
Depths (cm)												
5-10	140.72	143.30	94.28	143.69	107.87	103.27	2.70	2.29	2.18	2.95	1.84	1.61
10-20	36.98	28.45	30.53	61.55	42.95	21.28	1.07	0.68	0.00	1.55	1.17	0.00
20-30	0.32	0.07	0.00	0.35	0.40	0.00	0.12	0.00	0.00	0.00	0.00	0.00

Table 8: Bioassay values (ppm) of quantities of phorate and disulfoton residues at different depths at different intervals after point and broadcast application

Application	Point application						Broadcast application					
Insecticide	Phorate			Disulfoton			Phorate			Disulfoton		
Period (days)	1	3	7	1	3	7	1	3	7	1	3	7
Depths (cm)												
5-10	145.21	135.10	74.57	129.53	97.27	98.83	2.33	1.93	1.73	2.75	1.67	1.53
10-20	36.44	29.83	25.09	41.87	39.80	20.55	0.88	0.60	0.00	1.40	1.57	0.00
20-30	0.28	0.06	0.02	0.27	0.31	0.00	0.11	0.00	0.00	0.00	0.00	0.00

EFFECT OF PLACEMENT OF SYSTEMIC INSECTICIDE GRANULES ON CONTROL OF PESTS INFESTING COWPEA.

These observations were made on the leaf miner (*Phytomyza horticola* Goureau), pea aphid (*Aphis craccivora* Koch.), flea beetle (unidentified), leaf webber (*Nacoleia vulgalis* Guen.) and pod borer (*Polyommatus boeticus* L.). The results are presented below:

On leaf miner infestation:

Table 9: Percentage infestation of leaf miner on the 10th day after application of systemic insecticide granules.

Insecticide	Phorate	Carbofuran	Disulfoton
Placement			
Broadcast	13.90 (21.89)	26.37 (30.89)	23.79 (29.19)
All row	25.99 (30.65)	17.49 (24.72)	22.30 (28.18)
Alternate row	19.31 (26.07)	23.18 (28.78)	17.00 (24.35)
Point	24.47 (31.61)	31.45 (34.11)	31.20 (33.96)
Control		53.50 (47.01)	

C.D. for angles = 4.297

Angular values in parenthesis

Data presented in Table 9 and Fig. 11 showed that all the insecticidal treatments were significantly (Appendix VII) effective in controlling the leaf minor infestation and thus as against 53.5% infestation under control, the infestation under different insecticidal treatments varied from 13.90 to 31.45%. With phorate granules, broadcast application gave the best control (13.9% mean infestation) and was statistically superior to all other treatments in controlling the insect. Alternate row application ranked next with 19.31% infestation. This was followed by all row and point applications (25.99 & 24.47%) which gave significantly lower control than other treatments. These between themselves were on par.

For carbofuran granules, all row application gave the best result with 17.49% infestation and this was siginificantly superior to all others. Broadcast and alternate row applications with 26.37% and 23.18% infestations ranked next, they among themselves being on par. Point application, with 31.45% infestation, was the least effective and significantly inferior to all other treatments. In the case of disulfoton, alternate row application with an infestation of 17.00% gave the best control of the pest with all row application and broadcast application with

22.3 and 23.79% infestations ranked next, which were on par between themselves. The point application with 31.2% infestation was the least effective and significantly inferior to others.

On aphid infestation:

Table 10: Mean number of aphids (*Aphis craccivora* Koch.) on the 20th day after application of systemic insecticide granules.

Insecticide	Phorate	Carbofuran	Disulfoton
Placement			
Broadcast	22.90 (4.68)	23.09 (4.70)	25.60 (4.96)
All row	17.48 (4.06)	20.01 (4.36)	19.40 (4.29)
Alternate row	17.89 (4.11)	23.94 (4.79)	22.72 (4.66)
Point	27.73 (5.17)	32.47 (5.61)	35.46 (5.87)
Control	84.54 (9.14)		

C.D. (for transformed values) = 1.157

$\sqrt{x+1}$ values in parenthesis

Data (Table 10 & Fig. 12) presented show that all insecticide treatments gave significant control of aphid infestation (Appendix VIII). As against 84.54 aphids per

Fig. 11-15 Effect of placement of systemic insecticide granules of phorate, carbofuran and disulfoton on pest infestation of cowpea.

Fig. 11 Percentage infestation of leaf miner on the 10th day after application of granules of phorate, carbofuran and disulfoton.

Fig. 12 Mean number of aphids on the 20th day after application of granules of phorate, carbofuran and disulfoton.

Fig. 13 Mean number of holes caused by flea beetle on the 30th day after application of granules of phorate, carbofuran and disulfoton.

Fig. 14 Percentage infestation of leaf webber on the 20th day after application of granules of phorate, carbofuran and disulfoton.

Fig. 15 Percentage infestation of pod borer on the 40th day after application of granules of phorate, carbofuran and disulfoton.

EFFECT OF PLACEMENT OF SYSTEMIC INSECTICIDE GRANULES ON PEST INFESTATION ON COWPEA.

FIG. 11. LEAF MINER

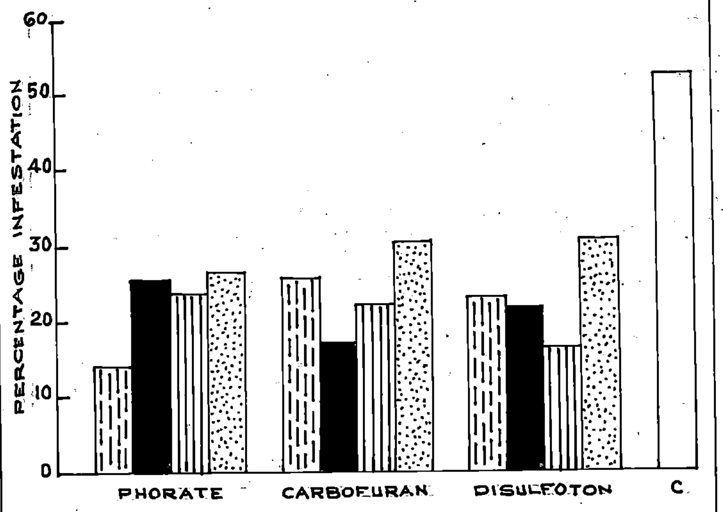


FIG. 12. APHID

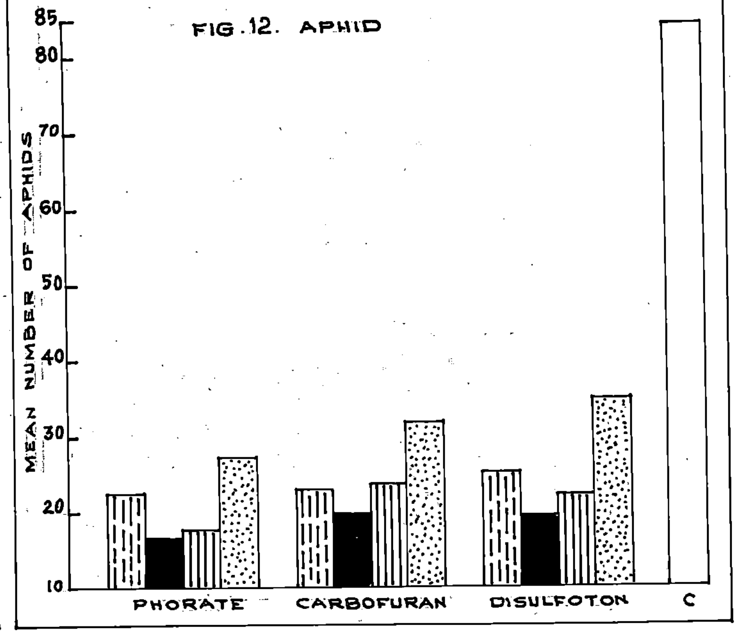


FIG. 13. FLEA BEETLE

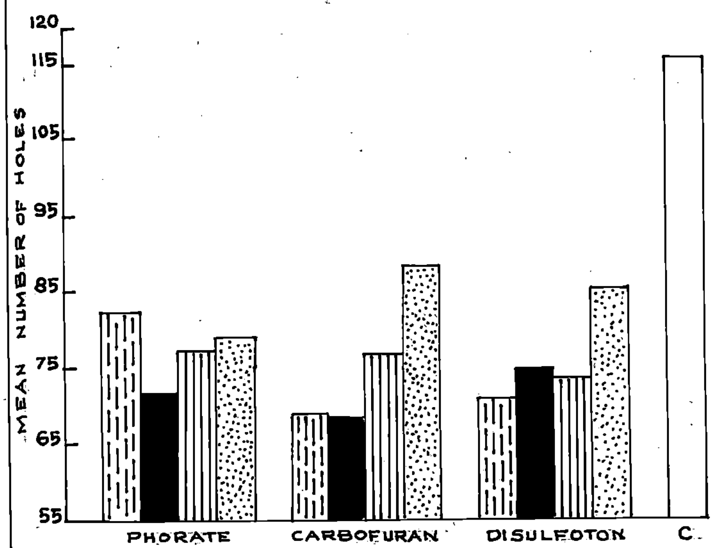


FIG. 14. LEAF WEBBER

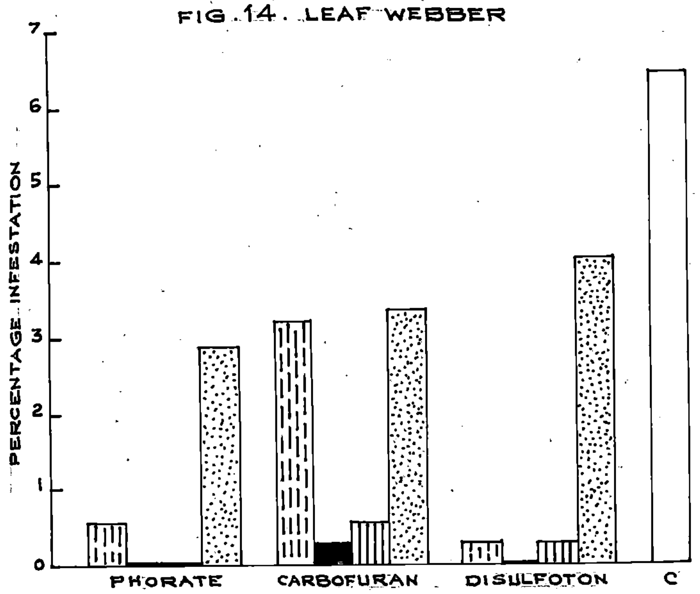
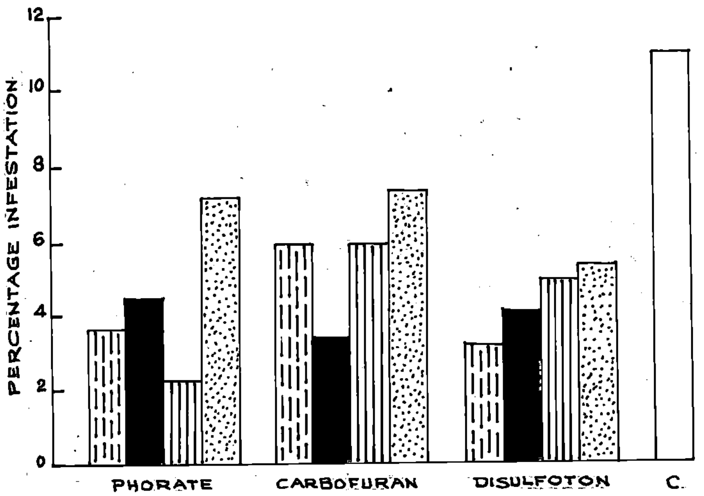
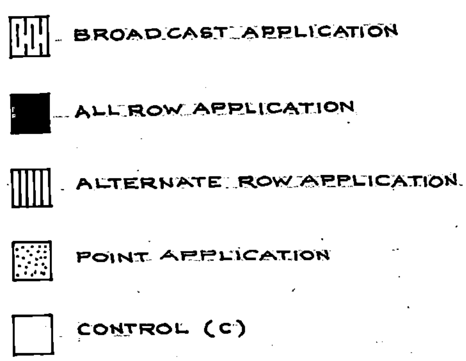


FIG. 15. POD BORER





plant on untreated control, the number of aphids varied from 17.48 to 35.46 under the different treatments. Under phorate, all row application gave the best control with 17.48 aphids per plant followed by alternate row application (17.89), broadcast (22.9) and point application (27.73), all the treatments being on par in their effects. With carbofuran, all row application with 20.01 aphids was significantly better than all the other treatments, the aphid populations being 23.09 to 32.47. In disulfoton, all row treatment with 19.4 aphids, was significantly superior to all other treatments, alternate row with 22.72 aphids ranked next, broadcast and point applications were inferior with 25.60 and 35.46 aphids respectively.

On flea beetle infestation:

All the insecticides gave significant control of the flea beetle infestation (Table 11 & Fig. 13). When the infestation was to the extent of 116 holes per leaf under control, under the various treatments, it varied from 69.17 to 88.83. Under all the three insecticides, the different placements did not give significant variation in their effect on the control of the flea beetle (Appendix IX).

Table 11: Mean number of holes caused by flea beetle on the 30th day after application of systemic insecticide granules.

Insecticide	Phorate	Carbofuran	Disulfoton
Placement			
Broadcast	83.83	69.67	71.50
All row	72.50	69.17	74.67
Alternate row	78.17	77.83	74.00
Point	79.83	88.83	85.67
Control	116		

C.D. = 21.78

On leaf webber infestation:

From the data presented (Table 12 & Fig. 14), it may be seen that phorate granules gave absolute control of the leaf webber infestation when applied in both the row applications (Appendix X). Broadcast application with 0.57% infestation as against 6.49% in control ranked next. Point application with 2.88% infestation was ineffective as compared with control. Carbofuran granules gave significant control under the two row treatments (0.28 & 0.57% infestations). Point and broadcast applications did not show significant effects. With disulfoton, all row

Table 12: Percentage infestation of leaf webber on the 20th day after application of systemic insecticide granules.

Insecticide.	Phorate	Carbofuran	Disulfoton
Placement			
Broadcast	0.57 (4.31)	3.24 (10.37)	0.28 (3.04)
All row	0.00 (0.00)	0.28 (3.03)	0.00 (0.00)
Alternate row	0.00 (0.00)	0.57 (4.31)	0.28 (3.03)
Point	2.88 (9.60)	3.38 (10.59)	4.08 (11.65)
Control	6.49 (14.76)		

C.D. for angles = 8.841

Angular values in parenthesis.

treatment gave absolute control. Broadcast and alternative row application gave significant control and were on par. Point application was ineffective.

On pod borer infestation:

Results of the treatments on pod borers (Table 13 & Fig. 15) show that as against 11.1% infestation under control, the infestation under the treatments varied from 2.39 to

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Table 13: Percentage infestation of pod borer on the 40th day after application of systemic insecticide granules

Insecticide	Phorate	Carbofuran	Disulfoton
Placements			
Broadcast	3.59 (10.92)	6.04 (14.23)	3.26 (10.40)
All row	4.53 (12.29)	3.41 (10.65)	4.22 (11.84)
Alternate row	2.39 (8.90)	5.98 (14.15)	4.98 (12.90)
Point	7.40 (15.78)	7.55 (15.94)	5.42 (13.46)
Control	11.10 (19.46)		

C.D. for angles = 5.19

Angular values in parenthesis

7.55%. With phorate, point application (7.4) did not give significant reduction (Appendix XI), while the other placements reduced the infestation significantly and were on par. In carbofuran, the point application (7.55) did not give significant control of the infestation. All row application gave the best result (3.41) while broadcast and alternate rows gave less control (6.04 & 5.98). Disulfoton gave significant control of pod borer under all the placements, the different placements being on par in their effectiveness (3.26 to 5.42).

EFFECT OF DIFFERENT PLACEMENTS IN SOIL ON THE PERSISTENCE OF SYSTEMIC INSECTICIDES IN COW PEA

The data presented in Table 14 and Figs. 16, 17 & 18 show that all the three insecticides under their different placements persisted in the soil up to 50 days and beyond after application. In phorate, the different placements gave 74.85 to 99.43% mortality, 10 days after application and 50 days after application, the mortalities were 11.22 to 28.08%. Among the different methods of application, all row application giving a mean mortality of 77.0% was the most highly effective followed by broadcast application giving 74.85% mean mortality and alternate row application with 74% mortality. Point application was the least effective (52.65%) which was significantly inferior to other placements. The other three applications were on par statistically (Appendix XII). In the case of carbofuran, the initial toxicity of the treatment as observed on the 10th day after application varied from 75.70 to 96.64% and this was reduced to 12.60 to 23.34% on the 50th day. The most efficient method of placement was broadcast application with mean mortality of 75.9% followed by all row application (72.15) and alternate row (65.45). These three were on par in their relative efficacy. The point application giving

Figs. 16-18 Residual toxicity of insecticides to adults of *Aphis craccivora* under different placements.

Fig. 16 Percentage mortality of aphis on cowpea under different placements of phorate in soil, 10, 20, 30, 40 and 50 days after application.

Fig. 17 Percentage mortality of aphis on cowpea under different placements of carbofuran in soil, 10, 20, 30, 40 and 50 days after application.

Fig. 18 Percentage mortality of aphis on cowpea under different placements of disulfoton in soil, 10, 20, 30, 40 and 50 days after application.

RESIDUAL TOXICITY OF INSECTICIDES TO ADULTS OF *Aphis craccivora* UNDER DIFFERENT PLACEMENTS.

FIG. 16. PHORATE

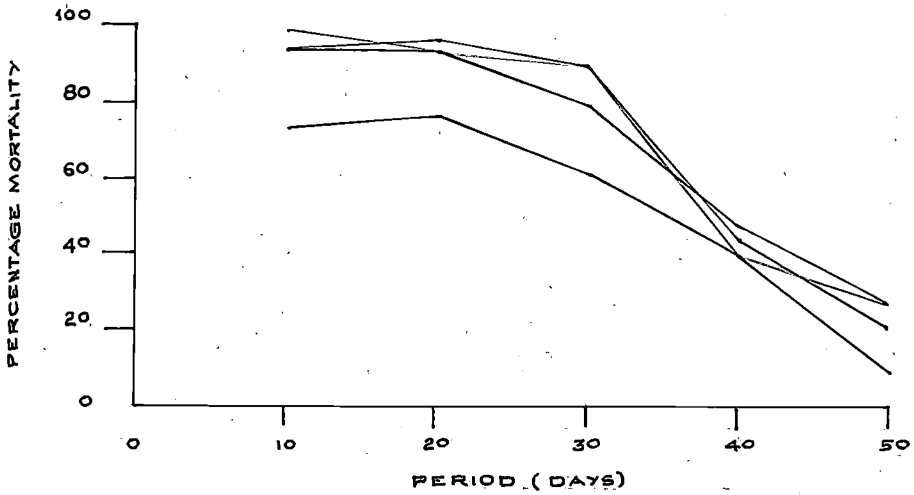


FIG. 17. CARBOFURAN

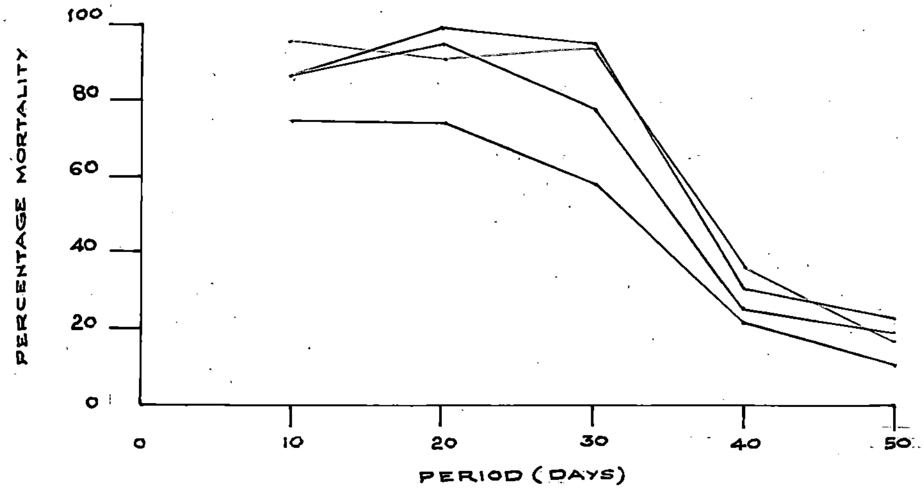
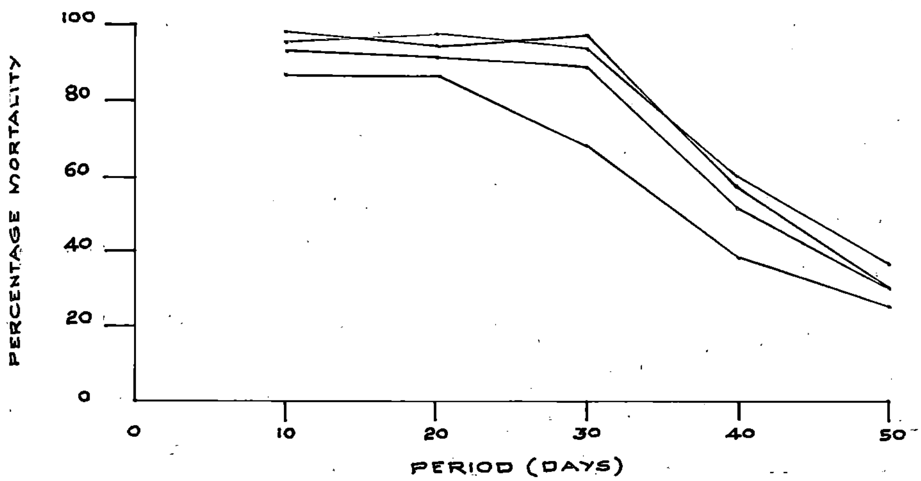


FIG. 18. DISULFOTON



BROAD-CAST APPLICATION
ALL ROW APPLICATION
ALTERNATE ROW APPLICATION
POINT APPLICATION

Table 14: Percentage mortality of aphids on cowpea under different placements of insecticides in soil at different intervals after application

Treatments		Interval - days					Mean
		10	20	30	40	50	
Phorate	Broadcast	95.30 (75.00)	97.63 (81.14)	90.75 (72.79)	44.82 (42.03)	22.83 (28.54)	74.85 (59.90)
,,	All row	99.43 (85.57)	94.72 (76.72)	90.75 (72.79)	41.50 (40.11)	28.08 (32.00)	77.00 (61.34)
,,	Alternate row	95.73 (78.07)	95.73 (78.07)	81.37 (64.43)	48.32 (44.04)	28.08 (32.00)	74.00 (59.32)
,,	Point	74.85 (59.90)	76.29 (60.85)	62.28 (52.11)	41.50 (40.11)	11.22 (19.57)	52.65 (46.51)
Carbofuran	Broadcast	88.14 (69.86)	100.00 (90.00)	96.49 (79.18)	31.45 (34.11)	25.34 (29.89)	75.90 (60.61)
,,	All row	96.64 (79.43)	92.30 (73.89)	95.30 (75.00)	36.52 (37.18)	18.16 (25.22)	72.15 (58.14)
,,	Alternate row	88.10 (69.82)	96.64 (79.43)	79.48 (63.07)	27.44 (31.59)	19.33 (26.08)	65.45 (54.00)
,,	Point	75.70 (60.47)	75.69 (60.46)	59.02 (50.19)	23.20 (28.79)	12.60 (20.79)	48.50 (44.14)
Disulfoton	Brodcast	98.86 (83.86)	95.19 (77.32)	98.45 (82.85)	58.50 (49.89)	31.45 (34.11)	82.75 (65.49)
,,	All row	96.64 (79.43)	98.86 (83.86)	95.30 (75.00)	60.65 (51.15)	37.90 (38.00)	82.95 (65.61)
,,	Alternate row	94.91 (76.97)	95.83 (75.61)	91.00 (72.54)	53.43 (46.97)	31.22 (33.97)	76.80 (61.21)
,,	Point	88.94 (70.58)	89.23 (70.83)	69.30 (56.35)	39.93 (39.19)	26.36 (30.89)	64.70 (53.57)
Control		0.00	0.00	0.00	0.00	0.00	0.00

C.D. for Mean (Angles) = 9.22
(Values in parentheses are angular transformations)

6

a mean mortality of 48.50% was the least effective and significantly inferior to the others. Disulfoton treatments giving mortalities of 88.94 to 98.86% in the beginning, gave 26.36 to 37.90% on the 50th day. All row application and broadcast with mean mortality of 82.95 and 82.75% appeared to be the best methods of placement closely followed by alternate row treatment with 76.80% mortality. These were on par statistically. Point application with 64.70% mortality was significantly inferior to broadcast and all row application, but on par with alternate row application.

EFFECT OF PLACEMENT OF SYSTEMIC INSECTICIDE GRANULES ON GROWTH CHARACTERS & YIELD OF COWPEA

The effect of placement of insecticide granules on plant height, number of branches, weight of shoot, weight of root, length of tap root, number of nodules and dry weight of nodules of cowpea were assessed at different intervals after application, the results of which are given below:

Effect on height of plants

Table 15: Mean height of cowpea plants in cm on the 50th day after application of systemic insecticide granules under different placements.

Insecticide placements	Phorate	Carbofuran	Disulfoton
Broadcast	79.17	74.88	76.54
All row	69.11	76.75	82.17
Alternate row	75.54	84.21	76.92
Point	66.08	64.17	64.42
Control	56.00		

C.D. = 12.5

The mean height of cowpea plants observed on the 50th day after insecticide application is given in Table 15 & Fig. 19. In the phorate treated plants, maximum height was recorded by broadcast application (79.17) followed by alternate row application (75.54). In the all row application and point application, the height recorded were 69.11 and 66.08 which were significantly superior to control (56.00) (Appendix XIII). Carbofuran applied in alternate rows recorded the highest mean height of 84.21 and the other treatments were in the descending order of 76.75 for all row application, 74.83 for broadcast and 64.17 for point application. In the case of disulfoton also, maximum height was recorded by all row application (82.17) followed by alternate row application (76.92). Broad cast application (76.54) and point application (64.42) followed the other treatments in plant height.

Effect on number of branches.

Table 16: Number of branches in cowpea plants on the 50th day after application of systemic insecticide granules under different placements

Insecticide	Phorate	Carbofuran	Disulfoton
Placement:			
Broadcast	6.00	5.58	6.33
All row	5.83	5.92	7.33
Alternate row	5.67	6.75	6.00
Point	4.58	5.27	4.67
Control	3.17		

C.D. = 1.332

Fig. 19-21 Effect of placement of systemic insecticide granules on growth characters of cowpea plant

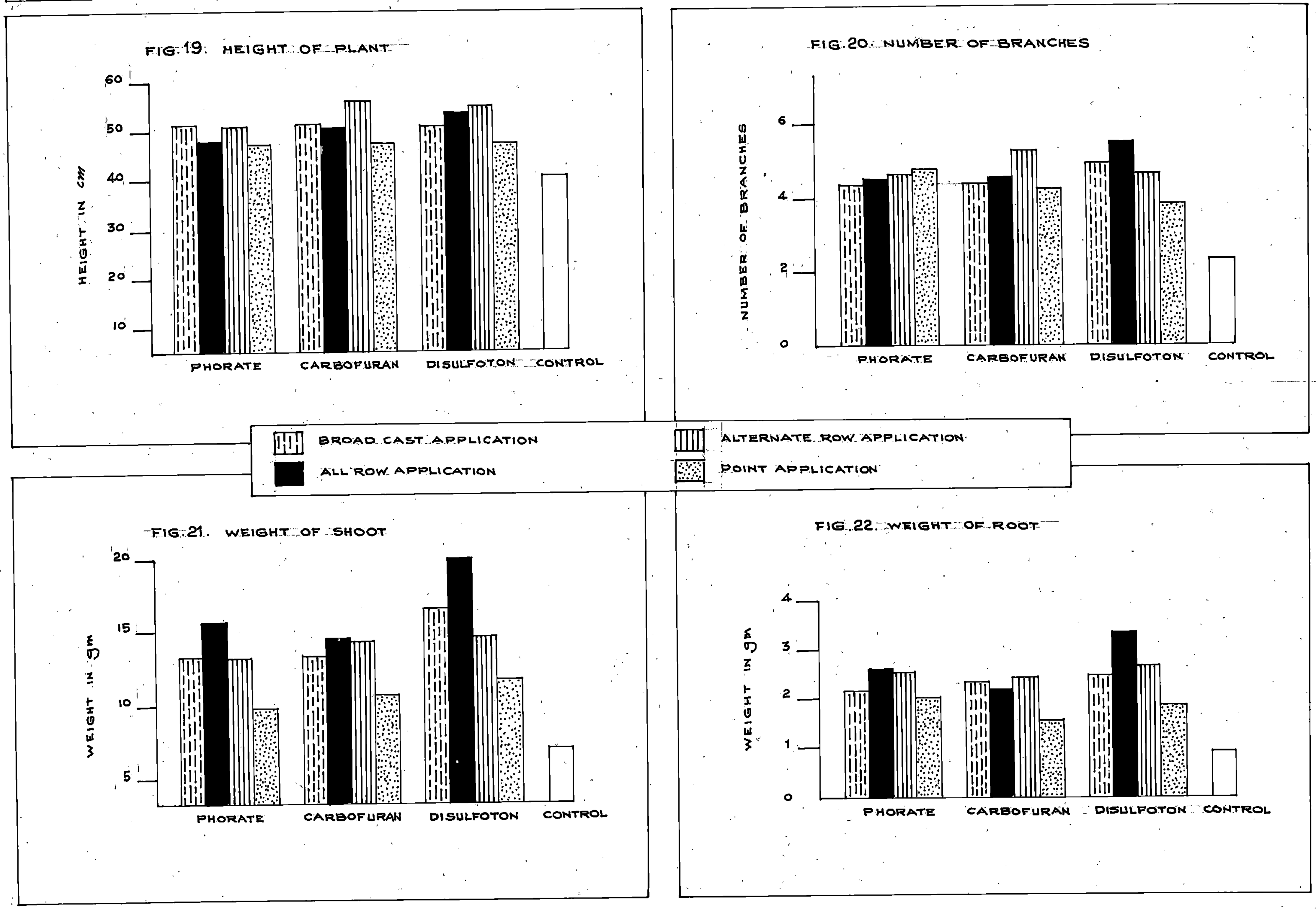
Fig. 19 Mean height of cowpea plants in cm on the 50th day after application of systemic insecticide granules under different placements.

Fig. 20 Mean number of branches in cowpea plants on the 50th day after application of systemic insecticide granules under different placements.

Fig. 21 Weight of shoot of cowpea plants in grams on the 20th day after application of systemic insecticide granules under different placements.

Fig. 22 Weight of root of cowpea plants in grams on the 20th day after application of systemic insecticide granules under different placements.

EFFECT OF PLACEMENT OF SYSTEMIC INSECTICIDE GRANULES ON GROWTH CHARACTERS OF COWPEA PLANTS.



Results presented in Table 16 and Fig. 20 showed that all treatments were superior over control (3.17) (Appendix XIV). In phorate maximum branches were produced by broadcast application (6.00) followed by all row application, alternate row application and point application, the number being 5.83, 5.67 and 4.58 respectively. Only the broadcast application gave significant increase in the number of branches. In carbofuran treatments, the maximum number of branches recorded by the alternate row treatment (6.75) over point application followed by all row, broadcast and point applications (5.92, 5.58 and 5.27 respectively). Only alternate row application was significantly superior to point application. In the case of disulfoton treatments, insecticide application in all rows gave the maximum number of 7.33 branches and other treatments were in the descending order of 6.33 for broadcast, 6.00 for alternate row and 4.67 for point application and all the treatments were significantly superior to point application.

Effect on weight of shoot.

The results given in Table 17 and Fig. 21 indicated that all the treatments increased the weight of shoot of cowpea plants significantly over control. Phorate and disulfoton showed similar effects on the increase in weight

Table 17: Weight of shoot of cowpea plants in grams on the 20th day after application of systemic insecticide granules under different placements

Insecticide	Phorate	Carbofuran	Disulfoton
Placement:			
Broadcast	13.54	13.57	16.55
All row	15.88	14.47	19.94
Alternate row	13.43	14.35	14.60
Point	9.77	10.72	11.91
Control	7.10		

C.D. = 1.647

of shoot giving 15.88 g and 19.94 g in all row application followed by 13.54 g and 16.55 g in broadcast application respectively. The least weight of 9.77 g and 11.91 g was observed in the point application with alternate row application giving a weight of 13.43 g and 14.6 g for phorate and disulfoton respectively. In phorate all row application was significantly superior to other treatments (Appendix XV) while in disulfoton, all row and broadcast applications were on par, but superior to other placements. In the case of carbofuran, the maximum weight was given by all row application (14.47 g) followed closely by alternate row application (14.35 g). Point application of carbofuran recorded the least weight of 10.72 g with broadcast application giving a weight of 13.57 g.

Effect on weight of root.

Table 18: Weight of root of cowpea plants in grams on the 20th day after application of systemic insecticide granules under different placements.

Insecticide	Phorate	Carbofuran	Disulfoton
Placement:			
Broadcast	2.24	2.29	2.50
All row	2.57	2.17	3.38
Alternate row	2.55	2.49	2.66
Point	2.04	1.54	1.89
Control	1.00		

C.D. = 0.91

The results presented in Table 18 and Fig. 22 indicated that all the treatments are found to increase the weight of root of plants significantly over control (Appendix XVI). Phorate and disulfoton application gave maximum weight of 2.57 g and 3.38 g respectively in all row application followed by 2.55 g and 2.66 g in alternate row application respectively. The least weight of 2.04 g and 1.89 g was found in the point application with broadcast application giving an intermediate effect of 2.24 g and 2.50 g respectively for phorate and disulfoton. For carbofuran treatments, the maximum weight was given by alternate row application (2.43 g) followed by broadcast (2.29 g) and all row application (2.17 g). The least weight was noticed in point application of the insecticide (1.54 g).

Effect on length of root.

Table 19: Length of tap root of cowpea plants in cm on the 20th day after application of systemic insecticide granules under different placements.

Insecticide	Phorate	Carbofuran	Disulfoton
Placement:			
Broadcast	15.50	16.17	18.66
All row	17.67	16.92	19.50
Alternate row	18.50	17.42	17.67
Point	12.50	15.50	17.17
Control	12.33		

C.D. = 2.93

The results are presented in Table 19 and Fig. 23 and statistical analysis in Appendix XVII. Among plants receiving phorate and carbofuran treatments, alternate row application produced the maximum length of 18.50 cm and 17.42 cm respectively followed by all row application

(17.67 cm and 16.92 cm respectively). The least length was observed in the point application (12.50 cm and 15.50 cm) with broadcast application showing an intermediate length of 15.5 cm and 16.17 cm for phorate and carbofuran respectively. In phorate treatment, excepting the point application all the other placements were significantly superior over control. Among disulfoton treatments, tap root length of 19.50 cm was observed in all row application followed by broadcast (18.66 cm) and alternate row application (17.67 cm). Point application of disulfoton registered a mean length of 17.17 cm. All treatments recorded significantly greater root length over control (12.33 cm).

Effect on the number of nodules.

The mean values of the data presented in Table 20 and illustrated in Fig. 24 indicated that insecticide treatment in general gave a higher number of nodules compared to control (8.00). Phorate application gave the maximum nodule number of 12.84 in broadcast application followed by alternate row application (11.00) and all row application (10.67). Point application gave the least nodule number of 8.17. In carbofuran, only the broadcast application gave significantly superior nodule number

Table 20: Number of nodules in roots of cowpea plants on the 20th day after application of systemic insecticide granules under different placements.

Insecticide	Phorate	Carbofuran	Disulfoton
Placement:			
Broadcast	12.84	14.00	12.84
All row	10.67	13.84	12.00
Alternate row	11.00	12.53	13.34
Point	8.17	8.67	7.83
Control	8.00		

C.D. = 4.72

compared to control (Appendix XVIII). Maximum nodule number was observed in broadcast (14.00) followed by all row application (13.84), alternate row application (12.53) and lastly point application (8.67). Broadcast and all row placements gave significantly increased number of nodules. In the case of disulfoton, maximum nodule number of 13.34 was observed in alternate row application followed by 12.84 of broadcast application. All row application of insecticides resulted in a nodule number of 12.00. The first two placements were superior over control. In the point application of disulfoton, the nodule number of 7.83 was lower than that of control plants (8.00).

Fig. 23-26 Effect of placement of systemic insecticide granules on growth characters and yield of cowpea plants.

Fig. 23 Length of tap-root of cowpea plants in cm on the 20th day after application of systemic insecticide granules under different placements.

Fig. 24 Mean number of nodules in roots of cowpea plants on the 20th day after application of systemic insecticide granules under different placements.

Fig. 25 Dry weight of nodules in milligrams on the 20th day after application of systemic insecticide granules under different placements.

Fig. 26 Yield of cowpea after application of systemic insecticide granules under different treatments.

EFFECT OF PLACEMENT OF SYSTEMIC INSECTICIDE GRANULES ON GROWTH CHARACTERS AND YIELD OF COWPEA PLANTS.

FIG. 23. LENGTH OF TAP ROOT

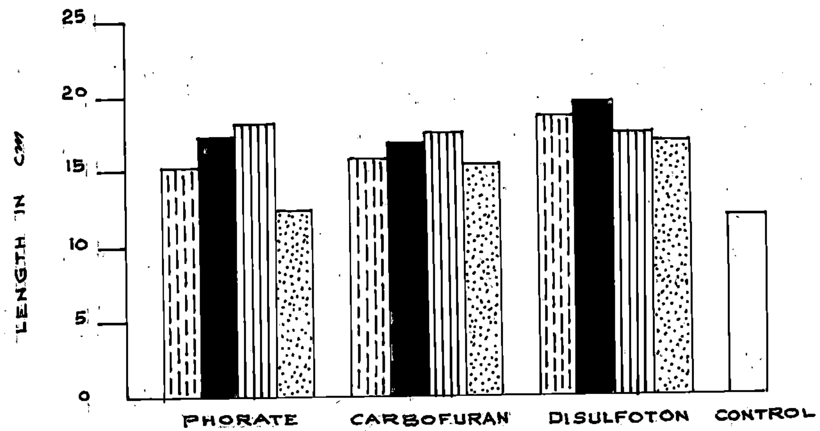
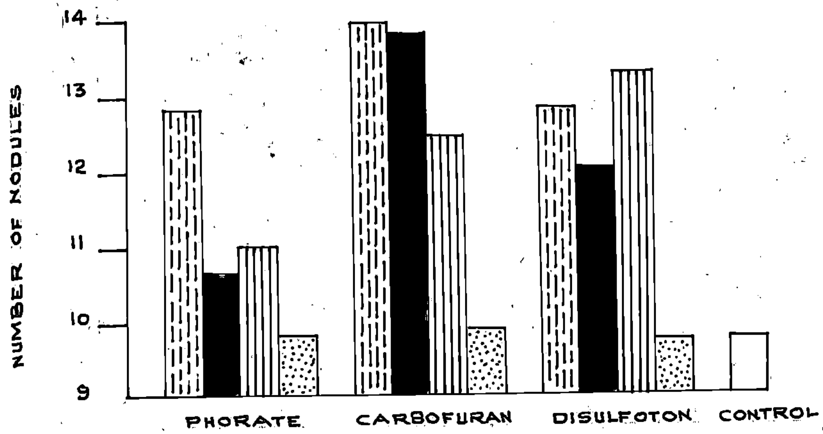


FIG. 24. NUMBER OF NODULES



BROAD CAST APPLICATION
ALTERNATE ROW APPLICATION
ALL ROW APPLICATION
POINT APPLICATION

FIG. 25. DRY WEIGHT OF NODULES

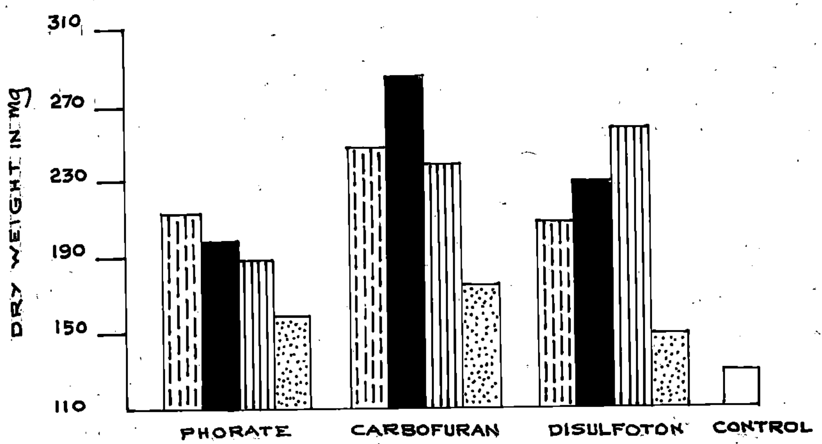
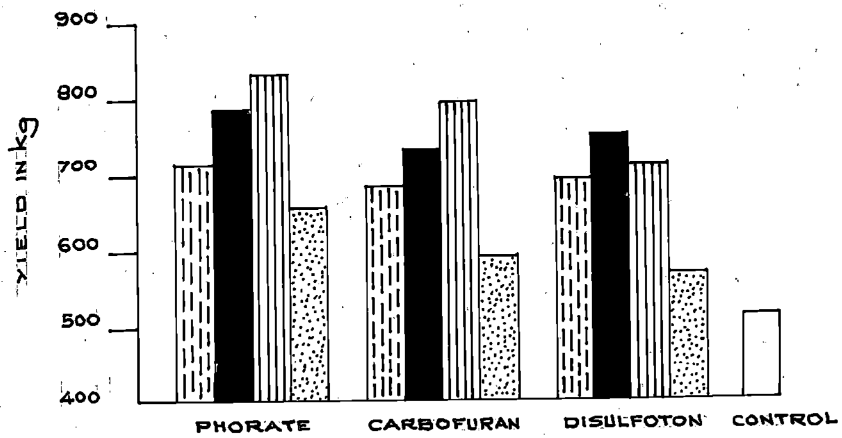


FIG. 26. YIELD.



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Effect on dry weight of nodules.

Table 21: Dry weight of nodules in milligrams on the 20th day after application of systemic insecticide granules under different placements.

Insecticide	Phorate	Carbofuran	Disulfoton
Placement:			
Broadcast	215.33	248.84	212.00
All row	199.34	284.17	232.00
Alternate row	191.84	242.17	261.67
Point	164.84	175.84	151.67
Control	133.33		

C.D. = 98.90

Results in Table 21 and Fig. 25 show that all the treatments resulted in increased nodule weight over control (133.33 mg). Among phorate treated plants, broadcast application recorded the maximum weight of 215.33 mg followed by all row application (199.34 mg) and alternate row application (191.84 mg). Point application gave a mean nodule weight of 164.85 mg. In the case of carbofuran, all row application gave the maximum weight of 284.17 mg followed by broadcast application (248.84 mg) and alternate row application (242.17 mg) which were found to be significantly superior over control. Point application recorded the least mean weight of 175.84 mg. In the case of disulfoton, alternate row application produced the maximum weight of 261.67 mg followed in the descending order by all row application (232.00 mg), broadcast application (212.00 mg) and point application (151.67 mg). The alternate row application alone gave significant increase in the weight of nodules over control (Appendix XIX).

<u>Effect of placement of systemic insecticide granules on yield of cowpea.</u>

The results are presented in Table 22 and represented in Fig. 26 with statistical analysis in Appendix XX.

Results presented revealed that in the case of phorate maximum yield of 855.20 kg per hectare was observed in alternate row application followed by 790.78 kg per hectare from all row applied plots. Broadcast application recorded a mean yield of 719.41 kg per hectare which was higher than point application (654.29 kg per hectare). Carbofuran treatments also showed a similar trend in yield with 803.94, 736.61, 690.40 and 597.76 kg per hectare respectively for the different placements. But in disulfoton treated plots, maximum yield of 750.69 kg per hectare was noted in all row application followed by alternate row application

Table 22: Yield of cowpea in kg/ha under different treatments of phorate, carbofuran and disulfoton granules

Insecticide	Phorate			Carbofuran			Disulfoton		
Dose	Low	High	Mean	Low	High	Mean	Low	High	Mean
Placement:									
Broadcast	690.73	748.08	719.41	672.42	708.37	690.40	676.27	716.90	696.56
All row	782.42	799.13	790.78	653.60	819.62	736.61	693.49	807.89	750.69
Alternate row	754.37	916.02	835.20	685.38	922.50	803.94	669.65	767.62	718.64
Point	650.27	658.30	654.29	606.28	589.24	597.76	545.20	603.07	574.14
Control	524.15								

(718.64 kg per hectare). Broadcast and point application resulted in yields of 696.56 and 574.14 kg per hectare respectively.

Statistical analysis revealed that phorate application in general gave significantly higher yields of cowpea than carbofuran and disulfoton which were on par. The higher doses of all the three insecticides produced significantly higher yields compared to the lower doses. Placement of insecticides in alternate rows gave the maximum yields and was on par with all row application but superior to the other placements. Broadcast application also produced significantly higher yields than point application. However, all the treatments resulted in significantly higher yields compared to that of control (Appendix XX).

RESIDUES OF SYSTEMIC INSECTICIDES IN COWPEA PODS WHEN APPLIED AS GRANULES UNDER DIFFERENT METHODS OF PLACEMENTS

Data presented (Table 23 & Fig. 27) show that all the insecticides under all the methods of application left residues in the pods. The residues were higher in pods of plants receiving higher dosages of insecticides than the lower dosages. Phorate granules showed residues varying from 0.193 to 1.118 ppm under the different treatments. The mean values indicate that the residues were highest under the all row treatment and lowest in the point application, the broadcast and alternate row application giving residues of intermediate levels (0.407 to 0.613 ppm). Carbofuran granules left residues varying from 0.061 to 0.143 ppm under the different applications. As regards effects of placements on the residues, the values presented show that least mean residues of 0.066 ppm was observed under the point application and maximum of 0.127 and 0.126 ppm in broadcast and all row applications respectively; alternate row application gave a mean level of 0.103 ppm. In disulfoton, the residues ranged between 0.462 to 1.912 ppm under different treatments. Among the different placements, point application left least residues (0.54 ppm mean) and broadcast and all row applications the

Fig. 27-28 Residues of systemic insecticides in cowpea pods under different placements.

Fig. 27 Residues of systemic insecticides in cowpea pods estimated by colorimetry on the 45th day after application under different placements.

Fig. 28 Residues of systemic insecticides in cowpea pods estimated by bioassay on the 45th day after application under different placements.

RESIDUES OF SYSTEMIC INSECTICIDES IN COWPEA PODS UNDER DIFFERENT PLACEMENTS.

FIG. 27. COLORIMETRY

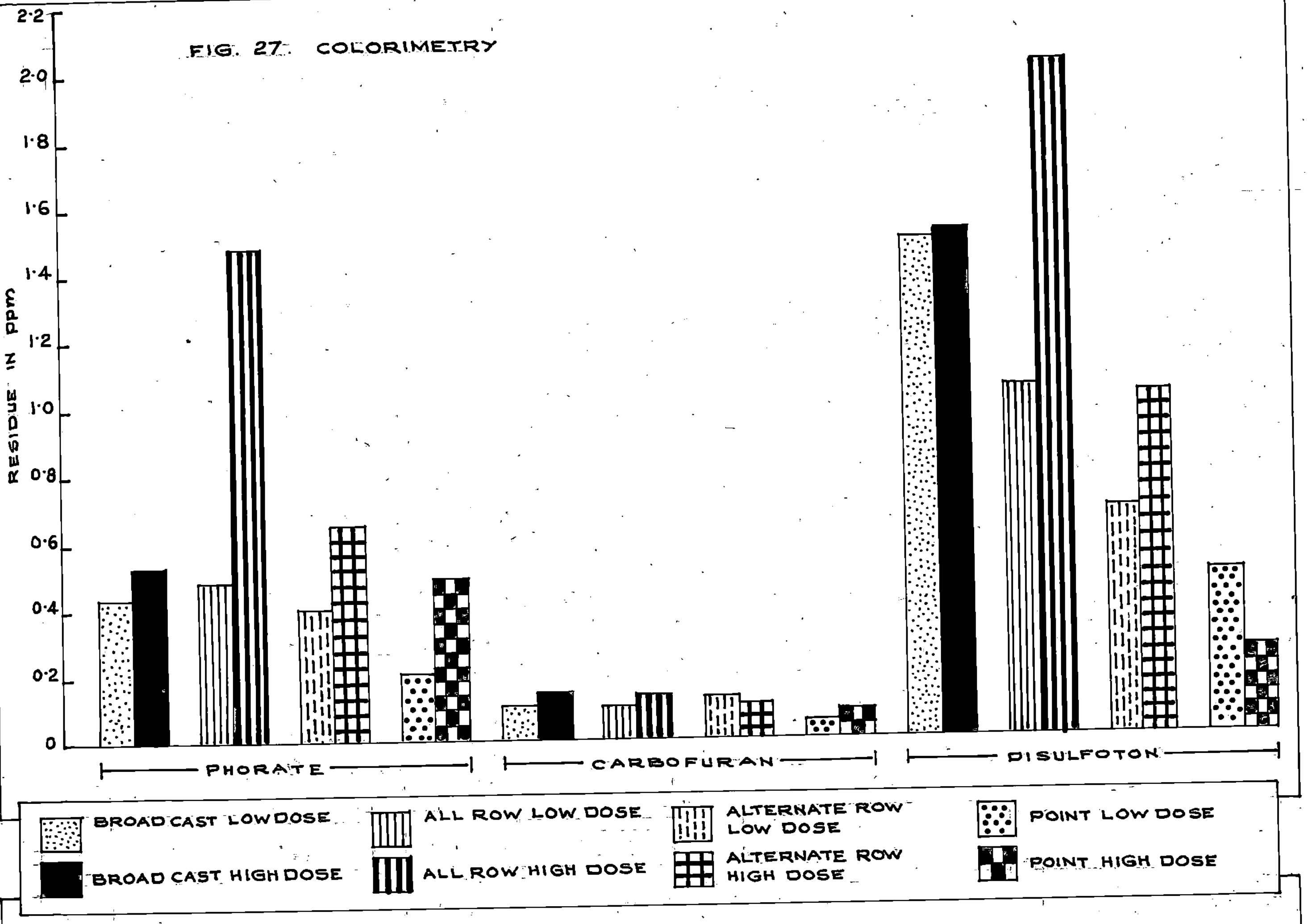

FIG. 28. BIOASSAY

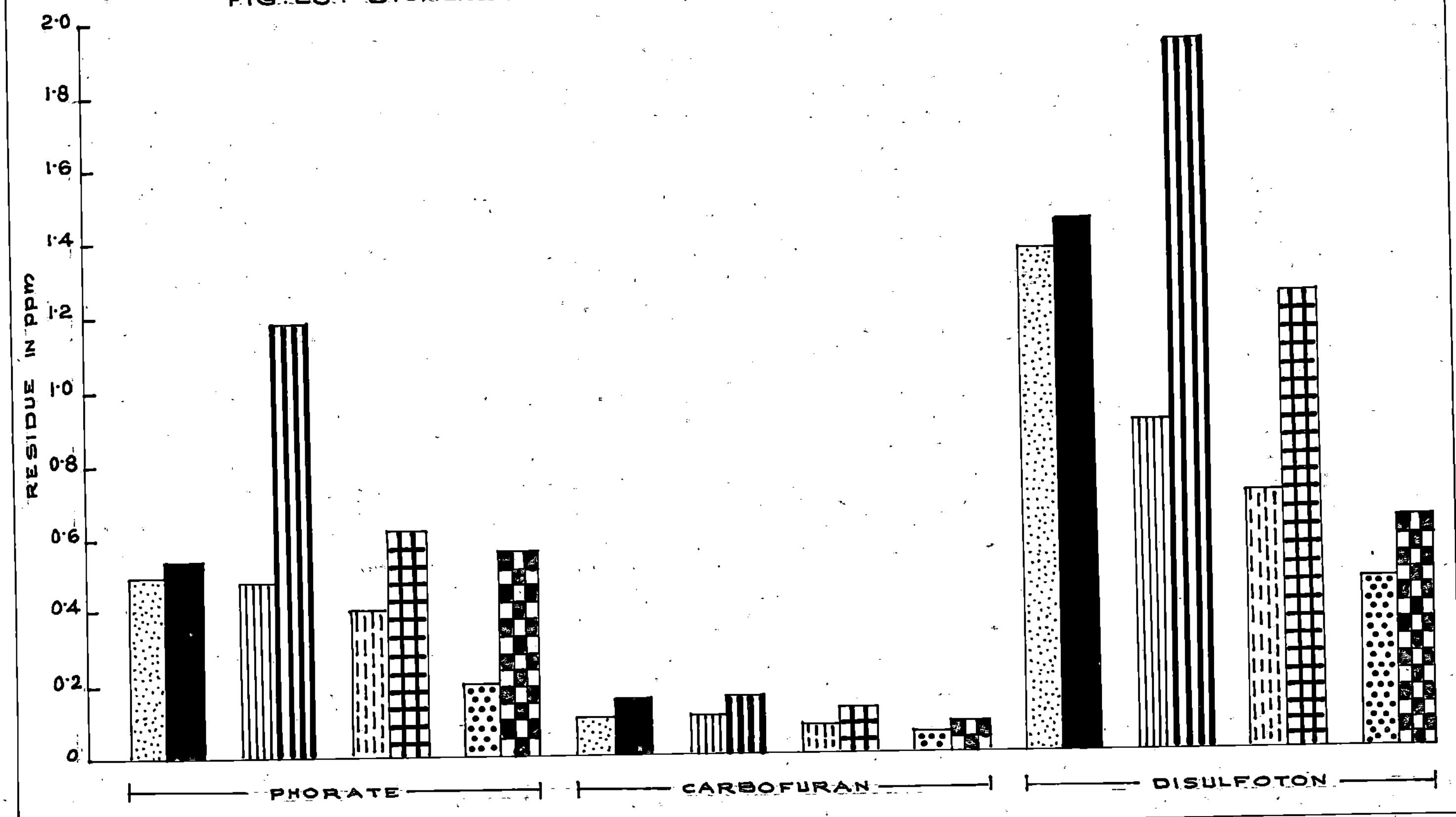

Table 23: Residues of systemic insecticides in cowpea pods under different treatments (Colorimetric estimation).

Insecticide	Phorate			Carbofuran			Disulfoton		
Dose	Low	High	Mean	Low	High	Mean	Low	High	Mean
Method of application:									
Broadcast	0.498	0.538	0.518	0.111	0.143	0.127	1.366	1.463	1.414
All row	0.476	1.118	0.797	0.111	0.141	0.126	0.896	1.912	1.404
Alternate row	0.407	0.613	0.510	0.094	0.112	0.103	0.708	1.220	0.964
Point	0.193	0.568	0.380	0.061	0.072	0.066	0.462	0.619	0.540

Table 24: Residues of systemic insecticides in cowpea pods under different treatments (Bioassay estimation).

Insecticide	Phorate			Carbofuran			Disulfoton		
Dose	Low	High	Mean	Low	High	Mean	Low	High	Mean
Method of application:									
Broadcast	0.432	0.540	0.486	0.100	0.138	0.119	1.492	1.514	1.503
All row	0.483	1.470	0.976	0.101	0.133	0.117	0.949	2.094	1.522
Alternate row	0.394	0.639	0.517	0.121	0.109	0.115	0.678	1.119	0.899
Point	0.207	0.483	0.345	0.048	0.072	0.060	0.491	0.267	0.379

COLLEGE OF AGRICULTURE

maximum (1.414 and 1.404 ppm mean). The alternate row application gave an intermediary level of 0.964 ppm mean.

The results of the bioassay estimations of residues presented in Table 24 and Fig. 28 indicate a comparable trend with values obtained after colorimetric estimation for the different insecticidal treatments.

DISCUSSION

DISCUSSION

In the present investigations, efforts were made to study the movement of systemic insecticides in soil in relation to the plane (horizontal and vertical) and as influenced by soil type. Since the movements and uptake of insecticides by plants were determined by their placements, studies were made to understand these relations with reference to growth, pest infestations, yield and residues in cowpea, the results of which are discussed below:-

Movement of insecticides in soils

The results presented show that the insecticides phorate, carbofuran and disulfoton when applied as granules moved in the horizontal plane. The movement was found to be easier in sandy soil while it was highly restricted in alluvial soil. In red and laterite soils, the movement was of intermediate efficiency. Thus in the case of phorate the insecticide reaching 80 cm from the point of application measured in terms of aphid mortality on cowpea plants was 17.83% in sandy soil, 1.23% in alluvial soil and 6.43 and 5.97% in red and laterite soils respectively. Similar relationships were observed with carbofuran and disulfoton

Table 25: Consolidated statement of percentage mortality of *Aphis craccivora* due to different insecticides at 80 cm distance from point of application in different soils.

Insecticide	Sandy soil	Alluvial soil	Red soil	Laterite soil
Phorate	17.83	1.28	6.43	5.97
Carbofuran	13.67	0.00	6.97	2.94
Disulfoton	10.73	0.00	7.05	3.29

also (Table 25). The difference in movement of the insecticides appeared to be correlated with the properties of the soils. The alluvial soil which had very high contents of clay (26.2%), silt (15.2%) and organic matter (6.2%) and a high cation exchange capacity (24.2 me/100g) restricted the movement of the insecticides considerably. On the other hand, sandy soil with very low clay content (6.0%), silt content (4.0%) and organic matter content (1.55%) and low cation exchange capacity (4.0 me/100g) facilitated rapid movement of insecticides. The red and laterite soils which had clay (10.9 & 12.3% respectively), silt (9.2 & 8.9% respectively), organic matter content (0.5 & 1.6% respectively) and cation exchange capacity (6.5 & 6.2 me/100g respectively) in between sandy and alluvial soils showed insecticide movements of intermediate intensities. The chemisorption of insecticides by silt and clay contents as pointed out by Visalakshi et al. (1979) in soils appeared to be involved in the present observations also.

The insecticides under study were found to move in the horizontal plane in soil to the maximum extent within 24 hours of application in all the soils except alluvial soil. In the case of alluvial soil, the maximum amounts of insecticide reached a point in 2 days. This again could be attributed to the resistance to movement offered by the alluvial soil. During periods following 24 hours in sandy, red and laterite soils and 48 hours in alluvial soil, there was a reduction in the insecticides taken up by the plants (Table 26).

Table 26: Consolidated statement of reduction of percentage aphid mortality in 4 days due to loss of available insecticides at 10 cm distance from point of application in different soils.

Insecticide	Sandy soil	Alluvial soil	Red soil	Laterite soil
Phorate	100.00-83.07	52.50-50.00	100.00-56.37	100.00-57.75
Carbofuran	100.00-75.22	42.65-30.00	98.46-32.42	100.00-34.55
Disulfoton	98.46-72.84	32.40-32.40	100.00-36.61	100.00-33.58

This reduction in the amount of the available insecticide differed in different soils. The decrease in the availability of the insecticides was least in the alluvial soil being 52.5 to 50.0% for phorate, 42.65 to 30.00% for carbofuran and 32.4 to 32.4% for disulfoton. The reduction of the availability of the insecticides during successive period of application was more in the other soils the extent of reduction being 100 - 83.07% to 100 - 33.38% in different soils for different insecticides. The larger persistence of the insecticides in alluvial soil could be attributed to the adsorptive retention of those insecticides on the clay particles and non-inactivating chemisorption by organic matter. Longer persistence of insecticides in soils with high organic matter has been reported by Lichtenstein (1965) and Wilson et al. (1966).

Among the insecticides, phorate appeared to move better than carbofuran and disulfoton and this feature was observed in sandy, alluvial and laterite soils. Thus in terms of aphid mortality, the mean insecticide equivalent reaching 80 cm from the point of application were 17.83, 13.67, 10.73% for phorate, carbofuran and disulfoton respectively in sandy soil; 1.28, 0.0 and 0.0% for alluvial soil and 5.97, 2.94 and 3.29 for laterite soil. In red soil.

this relation was however completely reversed (Table 25). As regards the persistence of the insecticides, phorate appeared to be more persistent than the other two insecticides and this feature was constant in all the types of soils (Table 26).

As regards the effect of the age of the plant on uptake of the insecticide moving in the horizontal plane, the results presented showed that the uptake was more in the case of 40 day-old plants than 20 and 10 day-old plants (Table 6). This could be attributed to the more extensive root system of the grown-up plants.

As different from the horizontal movement, the observations presented on the vertical movement of the insecticides showed a different pattern. These observations made in red soil using phorate and disulfoton applied as granules showed that there was a considerable resistance in the downward movement of the insecticides. The depth up to which the insecticides moved substantially was 20 cm. This appeared to be due to the compaction of the soil particles. These findings agreed with those of Jain et al. (1974) and Suett (1975) who observed that phorate and disulfoton penetrated to depths of 10 - 15 cm.

Between the two types of applications, broadcast application left low residues both in surface soils and at deeper levels (Table 7).

Studies on the placement of systemic insecticide granules in soil.

Effect on pest incidence on cowpea

The results presented will show that all the systemic insecticides under trial viz. phorate, carbofuran and disulfoton when applied as granules 10 days after sowing were effective in controlling such pest of cowpea as leaf miner, aphid, flea beetle, leaf webber and pod borers. Among the different methods of placements studied, application of granules along rows (Table 27) between the plants was found to give better control of pests than when applied broadcast or at regular points in between rows. When the granules were applied in all the rows between the plants or in alternate rows, the all row application was found to be superior in effect over the alternate row application. Generally the insecticide granules are applied broadcast for the control of crop pests. The present studies, however, show that broadcast application gave significantly less effect than row applications. The superiority of row

Table 27: Consolidated statement on the relative effect (ranking a to d) of different placements of insecticide granules on pest infestation.

Insecticide	Placement	Percentage reduction				
		Leaf miner	Aphid	Flea beetle	Leaf webber	Pod borer
Phorate	Broadcast	a	c	d	c	b
	All row	d	a	a	a	c
	Alternate row	b	b	b	b	a
	Point	c	d	c	d	d
Carbofuran	Broadcast	c	b	b	c	c
	All row	a	a	a	a	a
	Alternate row	b	c	c	b	b
	Point	d	d	d	d	d
Disulfoton	Broadcast	c	c	a	c	a
	All row	b	a	c	a	b
	Alternate row	a	b	b	b	c
	Point	d	d	d	d	d

application was thus found to be the best method of application of insecticide granules. The difference between the effect of these two applications was evidently due to the availability of the insecticides for the plants. In the case of broadcast application, the insecticides got distributed by horizontal and vertical movement in the entire upper layer of the soil. As a result, the insecticide available in the root zone for uptake was limited. When the granules were applied in rows, the insecticide moved sideways horizontally and vertically and each row of the plant received the flow of the insecticide coming from either side. This appeared to improve the availability of the insecticide manifesting better results than broadcast. The movement of the insecticide appeared to be more efficient in the case of row application than in the case of point application as could be seen from the results presented. Though comparative effect of different placements of insecticides were not reported earlier, the row application as a placement had been found to give good results in different pulses against different insects (Cook et al., 1962; Skrentny and Ellis, 1970; Chang, 1971; Chaudhary et al., 1976).

Effect on persistence of insecticides in cowpea plants.

The results of the studies made on the persistence of the insecticide in cowpea under the different placements assessed in terms of aphid mortality showed that the insecticides persisting within the plants on different occasions were the least under the point application while they were significantly higher under the two row applications and broadcast application. It was thus clear that the availability of the insecticides was same under the broadcast and row applications and it was significantly low under the point application. It may be noted in this connection that both the studies on the residues of the pods and the persistence of the insecticides in the plants showed that the availability of the insecticides under the broadcast application was either as high as or higher than under row applications. However, the results on the control of the pests of cowpea and plant growth characters and yield indicated effects inferior to that of row applications. This anomalous position cannot be explained with the available information.

Effect on plant growth characters.

The results presented will show that all the insecticides gave better growth of the plants over the untreated

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plants. The growth parameters used for these studies were plant height, number of branches, weight of shoot, weight of root, length of tap root, number of nodules and dry weight of nodules and all these parameters were found to be increased when treated with insecticides. The improvement in growth due to the insecticide application could be due to the combined effect of pest control and stimulatory effect of the insecticides on plants. Among the different placements barring a few descrepancies, the row applications were giving the maximum increase in the growth parameters than the broadcast and point applications (Table 28). Thus these observations also were in confirmity with those on pest control and yield. Similar effect of insecticide granules on growth on pulses were reported by Adel-Salam et al., 1972; Chelliah, 1972; Gawaad et al., 1971; Pablo and Pangga, 1973; Moody and Bailey, 1974 and Anon a, b, c, (1976).

Effect on yield of cowpea.

All the three insecticides were found to give significant increase in the yield of cowpea pods when applied as granules in soil. As against a mean yield of 524.15 kg of cowpea seeds per hectare in the control plot, the treatments gave mean yields ranging from 545.20 to 922.50 kg per hectare

Table 28: Comparison of the relative effect (ranking to a to d) of different placements of insecticide granules on plant growth parameters.

Insecticide	Placement	Height	No. of branches	Wt. of shoot	Wt. of root	Length of tap root	No. of nodules	Dry wt. of nodules
Phorate	Broadcast	a	a	b	c	c	a	a
	All row	c	b	a	a	b	c	b
	Alternate row	b	c	c	b	a	b	c
	Point	d	d	d	d	d	d	d
Carbofuran	Broadcast	c	c	c	b	c	a	b
	All row	b	b	a	c	b	b	a
	Alternate row	a	a	b	a	a	c	c
	Point	d	d	d	d	d	d	d
Disulfoton	Broadcast	c	b	b	c	b	b	c
	All row	a	a	a	a	a	c	b
	Alternate row	b	c	c	b	c	a	a
	Point	d	d	d	d	d	d	d

under the different treatments (Table 22). The row applications were giving the maximum yield (759.35 and 795.96 kg per hectare) compared to broadcast (692.11 kg per hectare) and point application (608.72 kg per hectare) (Appendix XXX). Between the two row applications, they were on par. These results thus showed the superiority of the row applications in the control of the pests and which reflected in the yield also. Row application of insecticide granules were reported to increase the yield of pulses (Webster and Smith, 1962 and Skrontny and Ellis, 1970).

Effect on residues of insecticides in cowpea pods.

The analysis of the residues of the insecticides in pods showed that all the insecticides left residues in the pods. Thus it was seen that the insecticide residues persisted in the plants for a period of 45 days after their application. The insecticides might be persisting in the soil during this period. Among the three insecticides, disulfoton gave the maximum residues in pods (0.540 to 1.414 ppm), carbofuran the least (0.066 to 0.127 ppm), phorate gave residues of intermediate levels (0.380 to 0.797 ppm). Thus disulfoton appeared to be the most highly persistent followed by phorate and carbofuran. As regards the effects of placement on the residues, it was observed that in plants, the all row application gave the maximum residues followed by broadcast and alternate row applications. In the case of carbofuran and disulfoton, residues were approximately the same under the broadcast and all row applications closely followed by alternate row application. The point application gave significantly lower residues with all the insecticides. Thus the uptake of the insecticides in the case of broadcast application was found to be as high as the uptake under the row applications. It may also be observed that disulfoton left residues above the tolerance limit of 0.75 fixed by EPA, U.S.A. (Anon, 1971) in all the placements except point application. Excepting the high dose of phorate applied in all rows (1.118 ppm), all the other placements left residues below the tolerance limit of 0.75 ppm (Anon, 1971). But carbofuran did not leave any toxic residues above the permissible limit of 0.2 ppm in any of the placements.

SUMMARY

SUMMARY

Horizontal movement of systemic granular insecticides viz. phorate, carbofuran and disulfoton in different types of soils of Kerala was studied by observing mortality of pea aphid on cowpea plant at different distances from the point of application. In sandy soil, these insecticides moved to a distance of 80 cm in 24 hours. In alluvial soil, the maximum movement of the insecticides was observed to take place on the second day after application. The insecticides moved only to a distance of 60 cm. In red and laterite soils, all the insecticides moved up to 80 cm in 24 hours. During days following the application of insecticides, there was a reduction in the availability of the insecticides at all the points from the point of application in all the soils except alluvial soil. The availability of the insecticides was more with higher doses of the insecticides. Movement in the soils was more in the case of phorate than carbofuran and disulfoton.

Studies on effect of the age of cowpea plants on uptake of the insecticide moving in the red soil showed that the uptake was more in the case of 40 day-old plants compared to 20 and 10 day-old plants.

Observations on the vertical movement of the systemic insecticide granules in red soil indicated that they moved

in substantial amounts only up to 20 cm depth.

From field experiments undertaken to study the effect of different placements of the systemic insecticide granules in soil on pest infestation, it was observed that they were effective in controlling such pests of cowpea as leaf miner, aphid, flea beetle, leaf webber and pod borer. Among the placements studied, application of the granules along rows between the plants was found to give better control of pests than when applied as broadcast or at regular points in between rows.

Studies on the persistence of these insecticides in cowpea under different placements were made in terms of aphid mortality at different intervals after application of the insecticide granules. It was observed that persistence was higher in the two row applications and broadcast application and significantly low in the point application.

Observations made on plant growth characters such as plant height, number of branches, weight of shoot, weight of root, length of tap root, number of nodules and dry weight of nodules of cowpea plants showed that all the insecticides gave better growth of the plants over the untreated plants. Among the different placements, in general, the row applications gave the maximum increase in the growth characters than the broadcast and point applications. Observations made on the effect of different placements of these insecticides on yield revealed that the row applications gave the maximum yield followed by broadcast and point applications. However, all the placements were found to give significant increase in the yield of cowpea pods.

When the cowpea pods harvested from the different treatments were analysed for the insecticide residues, it was observed that disulfoton left the maximum residues in pods (1.414 ppm) followed by phorate (0.797 ppm) and carbofuran (0.127 ppm). Regarding the effect of placement on the residues, it was seen that maximum residues were detected under the broadcast application followed by row application. The point application gave the least residues in the pods.

Thus it could be affirmed in brief that among the placements, row application of systemic insecticide granules was superior with regard to control of pests of cowpea, growth characters and yield.

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* ORIGINAL NOT SEEN.

APPENDICES

APPENDIX I

ANOVA of the percentage mortality of <u>Aphis craccivora</u> on cowpea plants in sandy soil planted at different distances from point of application of insecticide granules, observed at different intervals after application.

Source	S.S.	D.F.	M.S.S.	F.	Inference
Distance (A)	76588.55	4	19147.14	284.76	*
Dose (B)	35.28	1	35.28	<1	
Insecticide (C)	4317.72	2	2158.86	32.11	*
Period (P) (Intervals)	17326.20	2	8663.10	128.84	*
A x B	89.24	4	22.31	<1	
A x C	1343.50	8	167.94	2.50	*
B x C	289.43	2	143.72	2.14	
A x P	773.98	8	96.75	1.44	
B x P	100.55	2	50.27	0.75	
C x P	949.96	4	237.49	3.53	*
Error	9548.12	142	67.24		

Distance means: 10cm = 76.65; 20cm = 65.96; 40cm = 50.48; 60cm = 33.32; 80cm = 20.23
C.D. = 3.79

Insecticide means: Phorate = 56.19; Carbofuran = 46.72; Disulfoton = 45.08
C.D. = 2.93

Period means: 1st day = 60.33; 2nd day = 51.15; 4th day = 36.51
C.D. = 2.93

* Significant at 5% level.

APPENDIX II

ANOVA of the percentage mortality of *Aphis craccivora* on cowpea plants in alluvial soil planted at different distances from point of application of insecticide granules observed at different intervals after application.

Source	S.S.	D.F.	M.S.S.	F	Inference
Distance (A)	25272.94	4	6318.24	126.94	*
Dose (B)	427.41	1	427.41	8.59	*
Insecticide (C)	2215.13	2	1107.57	22.25	*
Period (P) (Interval)	5025.52	2	2512.76	50.48	*
A x B	231.63	4	57.91	1.16	
A x C	581.59	8	72.70	1.46	
B x C	109.09	2	54.55	1.09	
A x P	1209.82	8	151.23	3.04	*
B x P	57.81	2	28.90	<1	
C x P	1221.43	4	305.37	6.13	*
Error	7067.97	142	49.77		

Distance means: 10cm = 35.03; 20cm = 30.97; 40 cm = 21.20;
60cm = 14.14; 80cm = 2.05.
C.D. = 3.26

Dose means: Higher dose = 22.22; Low dose = 19.14.
C.D. = 2.06

Insecticide means: Phorate = 25.26; Carbofuran = 20.02;
Disulfoton = 16.75.
C.D. = 2.52

Period means: 2nd day = 26.23; 4th day = 22.24; 1st day = 13.60.
C.D. = 2.52

* Significant at 5% level.

APPENDIX III

ANOVA of the percentage mortality of *Aphis craccivora* on cowpea plants in red soil planted at different distances from point of application of insecticide granules, observed at different intervals after application.

Source	S.S.	D.F.	M.S.S.	F	Inference
Distance (A)	50444.04	4	12611.01	200.18	*
Dose (B)	1451.58	1	1451.58	23.04	*
Insecticide (C)	1060.47	2	530.22	8.42	*
Period (P) (Intervals)	23117.42	2	11558.71	183.48	*
A x B	267.61	4	66.90	1.06	
A x C	872.23	8	109.03	1.73	
B x C	475.55	2	237.78	3.77	*
A x P	4601.43	8	575.18	9.13	*
B x P	279.41	2	139.71	2.218	
C x P	203.85	4	50.96	0.81	
Error	8945.59	142	62.99		

Distance means: 10cm = 60.36; 20cm = 51.13; 40cm = 40.29;
60cm = 28.80; 80cm = 12.70.
C.D. = 12.70.

Dose means: Higher dose = 41.49; Lower dose = 35.81
C.D. = 2.32

Insecticide means: Phorate = 42.05; Disulfoton = 37.56;
Carbofuran = 37.34
C.D. = 2.84

Period means: 1st day = 53.15; 2nd day = 37.31; 4th day = 25.49
C.D. = 2.84

* Significant at 5% level.

APPENDIX IV

ANOVA of the percentage mortality of *Aphis craccivora* adults on cowpea plants in laterite soil planted at different distances from the point of application of insecticide granules, observed at different intervals after application.

Source	S.S.	D.F.	M.S.S.	F	Inference
Distance (A)	65918.62	4	16479.65	293.88	*
Dose (B)	1196.19	1	1196.19	21.33	*
Insecticide (C)	3617.27	2	1808.63	32.25	*
Period (P) (Intervals)	21851.34	2	10925.67	194.84	*
A x B	227.81	4	56.95	1.02	
A x C	473.88	8	59.23	1.06	
B x C	1393.48	2	696.74	12.42	*
A x P	4674.98	8	584.37	10.42	*
B x P	184.01	2	92.00	1.64	
C x P	447.25	4	111.81	1.99	
Error	7962.83	142	56.08		

Distance means: 10cm = 64.33; 20cm = 52.47; 40cm = 41.02;
60cm = 25.76; 80cm = 10.21
C.D. = 3.46

Dose means: High dose = 41.33; Low dose = 36.18
C.D. = 2.19

Insecticide means: Phorate = 45.08; Carbofuran = 35.99;
Disulfoton = 35.20
C.D. = 2.68

Period means: 1st day = 52.41; 2nd day = 38.45; 4th day = 25.43
C.D. = 2.68

* Significant at 5% level.

APPENDIX V

ANOVA for mortality of *Aphis craccivora* exposed on 10, 20 and 40 day old cowpea plants grown in red soil at different distances from the point of application of phorate after different intervals.

Source	S.S.	D.F.	M.S.S.	F.	Inference
Age (A)	412.54	2	206.27	4.68	*
Dose (B)	1280.27	1	1280.27	29.04	*
Distance (C)	19312.10	3	6437.37	146.01	*
Period (D) (Intervals)	8240.70	2	4120.35	93.45	*
A x B	272.82	2	136.41	3.09	*
A x C	1822.17	6	303.69	6.89	*
B x C	49.32	3	16.44	0.37	
A x D	1743.70	4	435.93	9.89	*
B x D	7.15	2	3.57	0.08	
C x D	3296.31	6	549.39	12.46	*
Error	4937.99	112	44.09		

Age means: 40 day old = 39.57; 20 day old = 37.04;
10 day old = 35.47
C.D. = 2.66

Dose means: High dose = 40.34; Low dose = 34.38
C.D. = 2.17

Distance means: 20 cm = 53.19; 40cm = 41.71; 60cm = 32.31;
80 cm = 21.64
C.D. = 3.07

Period means: 1st day = 47.49; 2nd day = 35.28; 4th day = 29.31
(Intervals)
C.D. = 2.66

* Significant at 5% level.

APPENDIX VI

ANOVA on the level of residues of phorate and disulfoton at different depths in soil on the 1st, 3rd and 7th day after point and broadcast application.

(after colorimetric and bioassay estimation)

Source	S.S.	D.F.	M.S.S.	F.	Inference
Insecticide (I)	2.90	1	2.90	<1	
Methods of estimation (M)	189.03	1	189.03	2.79	
Depth (D)	90807.39	2	45403.69	671.31	*
Period (P)	3224.02	2	1612.01	23.83	*
Application method (A)	89656.94	1	89656.94	1325.61	*
I x M	17.14	1	17.14	<1	
I x D	392.58	2	196.29	2.90	
M x D	125.06	2	62.53	<1	
I x P	236.67	2	118.33	1.75	
M x P	4.64	2	2.32	<1	
D x P	2322.29	4	580.57	8.58	*
I x A	5.56	1	5.56	<1	
M x A	169.42	1	169.42	2.50	
D x A	84646.99	2	42323.50	625.77	*
P x A	2826.27	2	1413.13	20.89	*
Error	7913.44	117	67.63		

Depth (D) means: 5-10cm = 59.96; 10-20cm = 17.70; 20-30cm = 0.13
C.D. = 3.32

Period (P) means: 1st day = 31.38; 3rd day = 26.57;
7th day = 19.84
C.D. = 2.71

Application method (A) means: Point application = 50.88
Broadcast application = 0.98
C.D. = 2.71

* Significant at 5% level.

APPENDIX VII

ANOVA for the percentage infestation of leaf miner after application of systemic insecticide granules on cowpea.

Source	df	MSS	F	Inference
Block	2	61.40	17.40	**
Treatment	12	118.30	33.42	**
Error	24	3.54		

C.D. for Treatment means = 4.297

** Significant at 1% level

APPENDIX VIII

ANOVA for the mean number of aphids after the application of systemic insecticide granules.

Source	df	MSS	F	Inference
Block	2	0.01	0.02	
Treatment	12	5.22	8.56	**
Error	24	0.61		

C.D. for Treatment means = 1.137

** Significant at 1% level.

APPENDIX IX

ANOVA for the flea beetle infestation (number of holes per leaf) after the application of systemic insecticide granules.

Source	df	MSS	F	Inference
Block	2	703.27	3.97	*
Treatment	12	461.45	2.60	*
Error	24	177.17		

C.D. for Treatment means = 21.78

* Significant at 5% level.

APPENDIX X

ANOVA for percentage infestation of leaf webber after application of systemic insecticide granules.

Source	df	MSS	F	Inference
Block	2	19.11	0.65	
Treatment	12	75.28	2.58	*
Error	24	29.20		

C.D. for Treatment means = 8.84

* Significant at 1% level.

APPENDIX XI

ANOVA for mean percentage of pod borer infestation after application of insecticide granules.

Source	df	MSS	F	Inference
Block	2	1.22	0.13	
Treatment	12	24.02	2.53	*
Error	24	9.50		

C.D. for Treatment means = 5.194

* Significant at 5% level.

APPENDIX XII

ANOVA for the pooled data of the percentage mortality of aphids exposed on cowpea plants at different intervals after application of systemic insecticides.

Source	df	MSS	F	Inference
Block	4	4999.68	171.10	**
Treatment	12	1476.67	50.54	**
Error	43	29.22		

C.D. for Treatment means = 9.22

** Significant at 1% level.

APPENDIX XIII

ANOVA on the effect of placement of systemic insecticide granules on the height of cowpea plants observed on the 50th day after application.

Source	df	MSS	F	Inference
Block	2	24.63	<1	
Treatment	12	190.76	6.58	**
Error	24	29.02		

C.D. for Treatment means = 12.30

** Significant at 1% level

APPENDIX XIV

ANOVA on the effect of placement of systemic insecticide granules on the number of branches of cowpea plants observed on the 50th day after application.

Source	df	MSS	F	Inference
Block	2	1.16	3.41	*
Treatment	12	3.32	9.77	**
Error	24	0.34		

C.D. for Treatment means = 1.332

* Significant at 5% level

** Significant at 1% level.

APPENDIX XV

ANOVA on the effect of placement of systemic insecticide granules on the weight of shoot of cowpea plants on the 20th day of application.

Source	df	MSS	F	Inference
Block	2	13.58	26.10	**
Treatment	12	31.41	60.40	**
Error	24	0.52		

C.D. for Treatment means = 1.647

** Significant at 1% level.

APPENDIX XVI

ANOVA on the effect of placement of systemic insecticide granules on the weight of root of cowpea plants on the 20th day of application.

Source	df	MSS	F	Inference
Block	2	0.70	4.38	**
Treatment	12	0.99	6.20	**
Error	24	0.16		

C.D. for Treatment means = 0.9135

** Significant at 1% level.

APPENDIX XVII

ANOVA on the effect of placement of systemic insecticide granules on the length of tap root in cowpea plants on the 20th day after application.

Source	SS	df	MSS	F	Inference
Block	6.5	2	3.25	1.97	
Treatment	171.81	12	14.32	8.68	**
Error	39.58	24	1.65		

C.D. for Treatment means = 2.93

** Significant at 1% level.

APPENDIX XVIII

ANOVA on the effect of placement of systemic insecticide granules on the number of nodules in roots of cowpea plants on the 20th day after application.

Source	SS	df	MSS	F	Inference
Block	2.73	2	1.37	<1	
Treatment	193.79	12	16.15	3.77	**
Error	102.81	24	4.28		

C.D. for Treatment means = 4.72

** Significant at 1% level.

APPENDIX XIX

ANOVA on the effect of placement of systemic insecticide granules on the dry weight of nodules in cowpea plants on the 20th day after application.

Source	SS.	df	MSS	F	Inference
Block	94.19	2	47.10	<1	
Treatment	72416.47	12	6034.71	3.22	**
Error	45014.15	24	1875.59		

C.D. for Treatment means = 98.90

** Significant at 1% level.

APPENDIX XX

ANOVA on the effect of placement of systemic insecticide granules on the yield of cowpea.

Source	df	MSS	F	Inference
Insecticide (A)	2	26121.11	5.11	*
Dose (B)	1	119252.28	23.32	**
Placement (C)	3	116653.51	22.82	**
A x B	2	2633.93	<1	
A x C	6	7361.17	1.44	
B x C	3	13651.32	2.67	
Factorial x Control	1	113812.21	22.26	**
Error	54	5112.30		

Insecticide (A) means: Phorate 749.91; Carbofuran = 707.17;
Disulfoton = 685.01
C.D. = 41.58

Dose (B) means: Low dose = 673.33; High dose = 754.72
C.D. = 45.01

Placement (D) means: Broadcast = 692.11; All row = 759.35;
Alternate row = 795.96;
Point = 608.35.
C.D. = 63.66

* Significant at 5% level

** Significant at 1% level.

ABSTRACT

The horizontal movement of three systemic granular insecticides phorate, carbofuran and disulfoton in four different types of soils of Kerala viz. sandy, alluvial, red and laterite, was studied by observing the mortality of aphids released on cowpea plants at different distances from point of application of the granules. The effect of age of cowpea plants on the uptake of phorate was assessed by growing plants of different ages. Vertical movement of phorate and disulfoton in red soil was assessed in terms of residue levels after broadcast and point application by colorimetric and bioassay methods.

The effect of placements of the systemic granules on pest infestation of cowpea was observed in a field experiment laid out in RBD and the incidence of leaf miner, aphids, flea beetle, leaf webber and pod borer was assessed. The effect of different placements of insecticides in soil on their persistence in cowpea was assessed by observing the mortality of aphids confined on the treated plants at ten-day intervals after application of the insecticide. The effect of placement of insecticide granules on plant growth characters viz. plant height, number of branches, weight of shoot, weight of root, length of tap root, number of nodules, dry weight of nodules and yield was assessed. Residues

were estimated in the green pods forty-five days after application of the systemic granules.

Results of the studies showed that except in alluvial soil, phorate, carbofuran and disulfoton, when applied in soil as granules, moved to a distance of 80 cm, in a period of 24 hours. In alluvial soil, movement was slow and only to a distance of 60 cm. The availability of the insecticide was reduced on days following the application of insecticides. In red soil, insecticides moved vertically to a depth of 20 cm.

The uptake of the insecticide was more in the older plants (40 day-old) than in younger plants(20 and 10 day-old).

The row applications of the insecticides were better in controlling the pests of cowpea than broadcast and point application. The persistence of insecticides in cowpea was higher under row applications and broadcast and lower under point application. The growth characters of cowpea and yield were of higher magnitudes in the row applications than the other placements. Residues of the insecticides in pods were higher under broadcast and row applications and lesser under point application.