CONTROL OF *Aphis craccivora* Koch. WITH FUNGAL PATHOGENS AND THEIR IMPACT ON THE NATURAL ENEMIES OF THE PEST

By

V. HAREENDRANATH

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DECLARATION

I hereby declare that this thesis entitled "Control of Aphis craccivora Koch. with fungal pathogens and their impact on the natural enemies of the pest" 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 titles of any other University or Society.

Place: Vellayani

Date : 7-3-1989.

V. HAREENDRANATH

CERTIFICATE

Certified that this thesis, entitled "Control of *Aphis craccivora* Koch. with fungal pathogens and their impact on the natural enemies of the pest" is a record of research work done independently by Mr. V. Hareendranath, 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.

Vellayani,

Dr.K.P.Vasudevan Nair
Chairman
Advisory Committee
Professor of Entomology

Approved By:

Chairman

Dr.K.P.Vasudevan Nair

Members

1. Dr.N.Mohan Das

2. Dr.S.Balakrishnan

3. Dr.P.B.Gopinathan

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INTRODUCTION

INTRODUCTION

Grain legumes form an important component in tropical cropping system. They serve as a cheap and easily available source of protein. The inherent capacity of legumes to enrich soil nitrogen act as an added incentive for extensive cultivation of the crop. In Kerala, cowpea is raised both for grain and vegetable purpose. The black cowpea aphid Aphis craccivora Koch. is a persistant pest of cowpea causing heavy damage to the crop. It feeds on stem, terminal shoots, flowers and tender pods. The depletion of plantsap by the feeding of the pest cause stunting of plants and delay in initiation of flowering. Moreover it also acts as a vector for a number of viral diseases.

Since the maximum incidence of pea aphid coincides with the active reproducive phase of the crop, attempts to control this pest through the insecticidal approach is beset with the danger of toxic residues remaining in the produce. Moreover, it may lead to destruction of natural enemies and consequent resurgence of this pest. In this context a feasible approach to combat the pest is to evolve an integrated pest management strategy with minimum use of insecticides. A sound knowledge of the ecology of the pest is an essential prerequisite for formulating such a strategy. Saharia (198) reported that rainfall, quality of food plant

and predators were the three important factors responsible for the population fluctuation of pea aphid. A number of coccinellid and syrphid predators are reported to play the role of efficient regulatory agents in nature. Fungal pathogens like Verticillium lecanii and Entomophthora sp. are also reported to cause natural epizootics in aphid populations. But, very little work has been done in Kerala on the role of these abiotic and biotic factors on the regulation of population of pea aphid (Jacob, 1963; Sarala Devi, 1967; Mathew et al., 1971). Hence the present investigation was initiated with a view to gather information on the population fluctuation of pea aphid in relation to weather factors and predator population and also to find out fungal pathogens of pea aphid with the potentiality for development as an effective biocontrol agent. With these objectives following studies were taken up.

1. Study on the influence of time of planting and stage of crop on the incidence of pea aphids and its predators.
2. Studies on the population fluctuation of pea aphid in relation to weather factors and predator population.
3. Survey and identification of fungal pathogens of pea aphid.
4. Pathogenicity studies on fungal pathogen and establishment of Koch's postulates.

5. Morphology of the proven fungus and symptomatology of fungal infection.
6. Studies on cultural characteristics of the fungus.
7. Evaluation of cheaper materials for mass production of the fungus.
8. Safety tests of the fungus on crop plants and predators.
9. Field tests to prove the efficacy of the fungus under field conditions in comparison with insecticidal treatment.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Importance of pea aphid Aphis craccivora Koch. as a pest

Aphis craccivora Koch. is a regular pest of cowpea (Vigna unguiculata). Lefroy (1909), and Krishnamoorthy (1928) reported A. medicagenis (A. craccivora) as a pest of cowpea. Aiyyar (1932) also reported it as a pest of various pulse crops. David (1953) reported A. craccivora attacking different pulse crops including field beans (Dolichos lablab), cowpea, leucerne (Medicago sativa). Evans (1954) reported A. craccivora as a pest of groundnut and as a vector of rosette disease of groundnut. Nair et al. (1976) reported the bean aphid A. craccivora as a serious pest of Lablab niger, Arachis hypogea, Gliricidia maculata, Phaseolus mungo, Phaseolus radiatus and other pulse crops. Aiyanna et al. (1978) while studying the pest complex of sun~flower (Helianthus annus) in Andhra Pradesh reported A. craccivora as one of the most important pests. Singh (1979) reported cowpea or groundnut aphid (A. craccivora) as a major pest of grain legumes. Gosh (1981) identified A. craccivora and A. gossypii as important pests of redgram. Melia (1982) reported A. craccivora as one among the seven species of aphids attacking citrus (Citrus lemon). Raju and Pande (1983) studied biology of A. craccivora on five

varieties of greengram (Vigna radiata).

The cowpea aphid A. craccivora is a wide spread pest on cowpea in India, Philippines, Thailand, Western USA and throughout much of tropical Africa and Latin America. (Jackai et al. 1986).

The pea aphid sucks the plant sap resulting in depletion of assimilants by the removal of plant sap coupled with an increase in the respiration of the plant. (Van, 1973). The nymphs and adults infest the tender shoots, inflorescence and the tender fruits or pods in large numbers and suck the sap. In early stages due to heavy drain of cell sap the tender shoots will dry up. Flower buds, flowers and tender pods will fall off prematurely. Tender pods may shrivel up and dry in due course (Nair et al. 1976). The aphids feed on stems, terminal shoots and leaf petioles and as plants mature they move to flowers and pods. Heavy feeding causes stunting of plants and delay in the initiation of flowering. Heavy attack on young seedlings can cause death of plants (Jackai et al. 1986).

The extent of damage caused by the pest has been estimated to be 15.87 per cent in groundnut. (Hariri and Tahan, 1983).

In addition to direct damage caused in legumes by its

feeding it also acts as a vector of diseases such as rosette, mottle, stunt and stripe in various legumes (Porter, 1984).

Population fluctuation of aphids in relation to weather factors

Gorham (1941) reported that population of Myzus persicae in potato was directly affected by climate. The rapidity with which infestation of species developed, depended on opportunity for over wintering in egg stage or breeding in such shelter. The number that migrated in July or early August was influenced by temperature and rainfall in June and early July. Since aphids feed on lower surface of potato leaves they were tolerant to changes in temperature and moisture. Lal and Singh (1947) studied seasonal history and ecology of wooly aphid (Eriosoma lanigerum) in Kumaon hills and reported that population was profoundly influenced by nature of its hosts, natural enemies and climatic condition. The mechanical action of wind and rain appeared to be negligible factors in determining pest population. Maximum number of aphids were observed when maximum temperature was above 90° F on several days. Gradual decline in population appeared to be due to increased humidity. Broadbent (1947) found that the aphid activity was positively correlated with maximum temperature of previous day and with evening reading

of dew point. It was negatively correlated with force of wind of previous afternoon but wind direction had a significant effect. Population changes from year to year probably depended to a great extent on summer rainfall.

Broadbent and Hollings (1951) reported that in several aphid species the survival at higher temperature depended largely on the water balance within the aphid. Aphids survive higher temperature when cooling is possible by evaporation. However, at a similar high temperature when humidity is high and evaporative ability is reduced survival period is decreased.

Real (1956) studied the bionomics of A. craccivora on groundnut in French West Africa. He observed that under high temperature and high humidity some second and third instar nymphs were found producing nymphs prematurely. Graham (1959) studied the effect of humidity on mortality and reproduction of spotted alfaalfa aphid Therioaphis maculata. He observed higher nymphal mortality in 65 to 70 per cent relative humidity at 25° and 20° C than 25 to 30 per cent, 40 per cent and 85 to 90 per cent relative humidity at the same temperature. A low humidity was found to be more favourable than a high humidity at all temperatures. The adverse effect of high humidity was lessened when the

temperature was decreased. A similar temperature humidity relationship has been found with green peach aphid M. persicae (Reed, 1964). Mortality of nymphs at 23.9 C and 29.4 C in 85 to 90 per cent relative humidity was lower than 40 per cent and 65 to 70 per cent relative humidity. At higher temperature high humidity was preferred. The reproductive period was not significantly affected by the change in relative humidity. There was no significant effect on longevity at 40 per cent, 65 to 70, and 85 to 90 per cent relative humidity. Longevity was the shortest at 65 to 70 per cent relative humidity at all temperatures. Radhakrishnan (1969) observed that the higher alate banana aphid Pentalonia nigronervosa population was correlated with higher relative humidity and lower aphid population was correlated with low relative humidity.

Jacob (1963) studied the fluctuation of pea aphid in relation to predators and weather factors. Peak population occured during the cold and summer months. Wind velocity exerted a significant negative influence and the other factors viz. maximum and minimum temperature, morning and evening humidity and rainfall did not have any significant influence on the population of aphid. Mathew et al. (1971) reported that there was no correlation between population of aphid and predator on the one hand and temperature and humidity on the other. Partial correlation studies showed that effect

of climatic factors were modified by the presence of predators. Saharia (1980) studied the natural regulation of population of A. craccivora on cowpea in Assam and reported that rainfall, quality of food plant and predators were the three important factors causing fluctuation of aphid population.

Herandez and Puga (1981) studied population dynamics of A. craccivora, A. gossypii and Tetraneura nigriabdominalis in field bean (P. vulgaris) and reported that average population size was negatively correlated with relative humidity. Berg (1984) studied the effect of temperature and host species on the population growth potential of cowpea aphid A. craccivora. The intrinsic rate of natural increase increased from 0 at 5° C to a maximum at 35° C. The reproductive period began earlier and was shorter at high temperature than at lower temperature. Rate of production appeared to be key determinant factor in population growth rate. The estimated lower temperature threshold for aphid development was 8.1° C. Harrington (1984) studied winter mortality, development and reproduction in a field population of M. persicae in relation to meteorological and biological factors. Leaf surface wetness and temperature were correlated significantly with rate of

population change but rainfall and wind were not. Growth and development continued throughout the winter. Hymenopterous parasites, fungus, Entomophthora species and predatory spiders did not affect winter survival.

Lal and Singh (1947) reported that for wooly aphid Eriosoma lanigerum maximum number was counted in May and June. Gradual reduction in number was noticed from June to September. Kolkalia and Soliman (1954) reported that in Egypt the activity of the aphid P. nigronervosa was greatest during winter months(December - January) with a temperature of 20-22° C and a relative humidity of 60-70 per cent. The alate forms appeared during the rainy period. As the temperature rose and the humidity fell during March - April, there was a reduction in alate population. Jacob (1963) while studying fluctuation of pea aphid population found that there was a rise in population of aphid in October which gradually declined during the first week of November and then gradually increased by the end of December. Menon and Christudas (1967) reported that the climatic conditions existing during the summer month and heavy rainfall were unfavourable for the banana aphid P. nigronervosa. The aphid infestation was higher during August to February when the temperature and rainfall were moderate.

Radhakrishnan (1969) observed that maximum population of winged alate banana aphid occurred during November and December - January. Mathew et al.(1971) reported that population of A. craccivora on cowpea was high during September to April. Herandez and Puga (1981) while studying population dynamics of A. craccivora, A.gossypii and Tetraneura nigriabdominalis, found that aphid population was generally low throughout the year and the largest number was recorded in November. Ghosh and Raychaudhari (1983) studied seasonal incidence of alate aphids especially A. craccivora, A. gossypii, Brachycaudus helichrysis, Lipaphis erysimi, M. persicae and Toxoptera aurantiae, in Kalimpong in West Bengal. Peak alate activity occured in March - April and from November to early January.

Predators and parasites of aphids

Population of aphids is controlled to a very great extent by their parasites and predators. Early work on predators of aphids include studies on Chilomenes sexmaculata Fabr. (Lefroy, 1909; Bagal and Trahan, 1945), Coccinella septumpunctata Linn. (Bagal and Trahan, 1945), Scymnus xerampelinus Muls. (Lefroy, 1909), S. quadrillum (Kapur, 1942), Chilocorus nigritus Fabr. (Rao et al. 1954), Brumus suturalis F. and Adonia variegata Goze (Kapur, 1942), Rodolia cardinalis

(Subramaniam, 1955), syrphid larvae (Deoras, 1942) and Sphaerophoria scuttallaris Fabr. (Lal and Gupta, 1953 and Lal and Haque, 1956). Reports also include Khan and Hussain (1965) recording B. suturalis as an important predator of groundnut aphid. Agarwala and Ghosh (1988) reviewed prey records of aphidophagous coccinellids in India. They reported B. suturalis Fab, coccinella septumpunctata L, Coccinella transversalis (Fab), Pseudoaspidimerus circumflexus (Motschulsky), Scymnus pyrocheilus Mulsant, Scymnus quadrillum Motschulsky, Scymnus xerampelinus Mulsant, Spitocaria bisellatta predating on A. craccivora.

Lefroy (1909) recorded C. sexmaculata as the commonest coccinellid in the plains. The larva hatching from egg started feeding on the aphids and required about 200 aphids a day and lived thus for 1 to 13 days. Bagal and Trahan (1945) reported the occurrence of C. septumpunctata in Bombay and found it feeding on the young nymphs of Peregrinus maidis. Kapur (1942) reported Scymnus nubilis Muls. and S. gracilus (Motsch.) as common predators of aphids and scales. Aphis laburni Kalt., A. gossypii Glov., A. maidis Fitch., A. nerii Fons. and M. persicae (Suls) were consumed by the adults and grubs of the predators.

Lal and Singh (1945) also noticed C. septumpunctata in the Kumaon hills feeding on all stages of Eriosoma lanigerum. Bagal and Trahan (1945) found that the adults of C. sexmaculata feed on the young nymphs of Perigrinus maidis on Sorghum. Hagen (1962) studied biology and ecology of predacious coccinellids viz. C. septumpunctata, C. sexmaculata, B. suturalis and Chelocorus nigritis. Atwal and Sethi (1963) studied the biochemical basis for food preference of C. septumpunctata for certain species of aphids and found that the predator preferred aphids whose protein content was most like that of the predator. Saharia (1981) studied biology of coccinellid predators associated with A. craccivora on cowpea. The aphid was predated by Coccinella rependa, M. sexmaculata, Spilocaris bisellatta and Harmonia dinudata. Duration of life cycle of predators varied according to species. M. sexmaculata have shortest life period and proved an effective predator in field because of its larger population and fairly high feeding rate of A. craccivora.

Sinha and Pandey (1982) studied the functional response of C. septumpunctata a coccinellid predator on mustard aphid Lipaphis erysimii and reported that there was a nonlinear relationship between consumption and density of L. erysimii indicating its searching capacity. Anand (1983) studied

predation by C. septumpunctata and M. sexmaculata on five species of aphids viz. L. erysimii, Brevicoryne brassicae, A. craccivora, Macrosiphum pisum and A. gossypii. L. erysimii was consumed in the largest number by both coccinellids and A. gossypii, the least.

Butani and Bharodia (1984) studied relationship between A. craccivora on groundnut and predators viz. Hippodermia varigata, C. septumpunctata and M. sexmaculata. A positive correlation was observed between aphid index and the population of active stage of predator during March, while in April aphid population decreased with increased abundance of coccinellids. The predator population had declined by first week of May, most of them having migrated to other areas due to decrease in prey abundance. It is also reported that application of insecticides is unnecessary if coccinellids are present in the groundnut crop in summer.

Bagal and Trahan (1945) reported that maximum number of aphids P. maidis consumed by individual larvae and pairs of adults of C. septumpunctata are 420 and 22574 respectively with an average of 106.29 under controlled condition. Jacob (1963) studied the biology and predatory potential of M. sexmaculata. The average feeding potential of the coccinellid beetle was found to be 27.2 pea aphids per day.

Sarala Devi (1967) studied the feeding potential and food requirements of the grubs and adults of C. sexmaculata and the feeding potential of adults of S. quadrillum and P. circumflexus on A. craccivora. The grubs of C. sexmaculata consumed on an average 8.98 aphids during the first instar, 24.13 aphids during the second instar and 58.76 aphids during the third instar. The adults consumed 27.22 aphids per day on an average life span of 33.1 days. Adults of S. quadrillum consumed on an average 9.28 aphids per day and 473.43 aphids during its wholelIfe lasting on an average 46.67 days. The adults of P. circumflexus had a feeding rate of 9.83 aphids per day and 276.8 during its life which lasted on an average 28.25 days. Ofuya (1986) studied predation of Cheilomenus vicina on the cowpea aphid A. craccivora under laboratory conditions and reported that early aphid instars were consumed in significantly greater numbers than later instars and females. Feeding rates had a significant positive correlation with the population density of prey.

Lefroy (1909) reported that about 67 species of syrphids were noticed in India.. They were commonly called as Hover flies. The syrphid larvae feed exclusively on aphids. Uttah (1940) found that in Delhi the syrphid larvae fed on a number of aphids which included Rophalosiphum pseudobrassicae

on safflower and M. avenae on wheat, barley etc. Deoras (1942) observed that a single syrphid larva destroyed about 484 aphids in 4 hours. Khan and Hussain (1965) observed that the syrphids formed a very important beneficial group of insects from the economic point of view in the control of groundnut aphids.

Of the syrphids S. scuttellaris was the most important aphidophagous species in India. Seetharaman (1966) reported that Xanthogramma scuttellare was the most important syrphid predator in Kerala. The population peaks of these flies were during November and March - April. He also recorded that a single larvaerequired on an average 123 aphids (A. craccivora) per day. Sarala Devi (1967) studied the feeding potential of X. scuttellare and reported that during its larval duration which lasted for an average of 5.07 days, the maggot consumed 382.86 aphids..

Raychaudhari (1979) reported Theriodium species as parasitic on A. craccivora. The bionomics of Trioxys indicus a parasitoid of A. craccivora was studied by Rajendra Singh et al. (1981) and reported that there was a linear relationship between mortality level of host and host density. In a 15 minute period each parasitic female was capable of attacking 46.8 aphids when host population was 100, but attacked only

12 aphids when host population was 25. Rajendra Singh and Sinha (1981) studied occurrence of nonproductive A. craccivora mummies from which no adult parasite or hyper parasite emerged and reported that temperature and long day condition resulted in mummies containing diapausing individuals of T. indicus or dead pre adult stage. Large number of T. indicus was found to enter diapause in late March and early April.

Monadjemi (1979) made a study of two strains of Aphelinus anychis Walk. parasitic on Rhopalosiphum maidis and A. craccivora. The development cycle for parasite lasted two to three weeks. Its reproductive potential was high and the parasitic activity of larva supplemented by predatory behaviour in adults. Rajendra Singh and Sinha (1983) reported T. indicus had a high searching ability and had a density dependent relationship with its host. A. craccivora appeared on pigeonpea in second week of December and estimated to increase until first week of April. T. indicus appeared in the field in about third week of December parasitising 9.4 per cent of aphid population. Parasitation reached a peak of 64.6 per cent in mid February resulting in suppression of aphid population. Parasite tend to be olygophagous.

Pandey and Rajendra Singh (1984) studied the bionomics of T. indicus an aphidid parasitoid of A. craccivora in laboratory and found that it had an average fecundity of 143 per female. Mean female development was 17.8 days and male development was 14.5 days. Mean adult female and male lifespan lasted 7.4 and 6.2 days in the absence of host and 6.55 dnd 4.55 days in the presence of host. Sex ratio of offspring was dependent on maternal age at oviposition, the production of female declining as age increased.

Fungi as biological control agents

Fungi are potentially the most versatile entomopathogen. Some have toxins and potential for quick damage. The fungi have some advantages that are almost unique among the entomogenous pathogens. They are able to infect through the host integument, so ingestion is unnecessary for infection. Certain aquatic fungi have some ability to search for host and they disperse naturally through air movement (Fuxa, 1987).

Insect mycoses are caused by fungi belonging to all the four major taxonomic groups viz. Phycomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes (Steinhaus, 1949). But the majority of publications on insect mycoses discuss Entomophthora, Beauveria, Metarrhizium, Aspergillus, Verticillium, Hirsutella, Culicinomyces, Lagenidium,and

Coelomomyces (Steinhaus, 1964; Roberts and Yendol, 1971; Ferron, 1981; Hall, 1981; Mc coy, 1981; Dean and Wilding, 1981). Comprehensive reviews are now available on insect fungal association, taxonomy, mode of infection, life history, propagation techniques and attempts at colonisation for insect pest suppression. (Steinhaus, 1949, 1964; Sweetman, 1958; Couch, 1963; Mc Even, 1963; Madelin, 1963, 1966; Muller - Kogler, 1965; Roberts and Yendol, 1971; Roberts, 1973; Bell, 1974; Ferron, 1981; Hall, 1981 and Fuxa, 1987).

Ramaseshiah (1967) reported that Myzus sp., Lipaphis sp. and Brevicoryne sp. were susceptible to fungal diseases caused by Entomophthora coronata. Dean and Wilding (1971) reported that the aphid Metapolophisium sp. and Sitobion sp. are susceptible to Entomophthora aphidis, E. planchoniana and E. thaxteriana. Zimmerman (1978) reported morphological characters of 17 species of Entomophthora pathogenic to aphids. Dean and Wilding (1981) reviewed epizootiology and development of Entomophthora forapest control. He reported that spread of Entomophthora in an insect population is influenced by abiotic factors essentially weather and biotic factors comprising density and distribution of host and fungus and inherent infectivity of the fungus. Skopina et al.

(1984) studied effect of E. thaxteriana Petch isolated from Aphis pomi Deg, and M. persicae. Mortality of aphids 24 hours after treatment with the fungus suspension was 20 to 30 per cent and after 48 hours it was 66 to 73 per cent. In darkness death of aphids increased to 99 per cent. Hussey and Tinsley (1981) reported that E. aphidis was studied in China as a potential biological control agent to control A. gossypii on cotton. Laboratory cultures are maintained in Czapek (Dox) agar medium and then bulked as a solid medium of bran and water (1:0.5 w/w). Growth was completed in four days at 24 C yielding a product with 3×10^8 conidia per g. Field experiment showed that conidial suspension containing 6×10^6 spores per ml killed 76 to 100 per cent A. gossypii, A. pomi, Sitobion avenae and M. persica. Better control was effected if solid substrate was soaked in water for 24 hours before use apparently because of soluble mycotoxins were included in the suspension.

Baird (1912) reported that in Barbados Cephalosporium lecanii was found effective against black scale Saissetia oleae. Artificial spraying of the fungal spore suspension caused 75 per cent mortality on the scales. In Granada C. lecanii was effective against Coccus mangifera as

reported by Smith (1912). Squibbs (1934) used the Indian strain of C. lecanii for control of scale insect of coconut in Seychilles. The pathogen proved effective when spore suspensions were applied to potted plants infected with scales. Evalakhova (1938) studied control of Ceroplastes sinensis Del Guer with C. lecanii. Spores were applied to infected mandarin orange scales as a dust and as a 10 per cent suspension in water, of which former method was found more effective. Viegas (1939) found that spore suspension of V. lecanii sprayed on cofee was effective in reducing the population of C. viridis in Brazil. Baird (1958) reported use of C. lecanii against scale insects in West Indies, Brazil, Peurto Ricca, India and Ceylon. Easwaramoorthy and Jayaraj (1977) reported that the fungus C. lecanii was used against guava scale Pulvinaria psidii (Sulz) and chilli aphid M. persicae. The fungus at the rate of 16×10^6 and 10×10^6 spores per ml against the scale and aphid respectively gave control of the insects. Easwaramoorthy and Jayaraj (1977) reported that pearl millett and potato extract as highly suitable for the growth of the fungus C. lecanii. Even-though tapioca and sweet potato extract favoured radial growth of the fungus, dry weight of mycelia was markedly diminished. Easwaramoorthy and Jayaraj (1978) reported that the White halo fungus C. lecanii was highly

effective in the control of coffee green bug Coccus viridis under field conditions. With two fortnightly applications of 16 x 10^6 spores per ml, 73.1 per cent mortality of the insect was noticed after second application. The fungus was more effective as a high volume spray than as a low volume spray. Hall (1981) reported the fungus V. lecanii as a microbial insecticide against aphids and scales. Thirteen varied successes in controlling aphids and scales by V. lecanii are reviewed and the fungus is reported effective against M. sanbornii, B. helichrysis, A. flavae and A. gossypii. Hall (1984) studied the epizootic potential for aphids to different isolates of the fungus V. lecanii. He reported that large (6.7 - 8.4 um in length) spored strains of V. lecanii killed similar number of adult aphids treated with aqueous suspensions. Large spored strains exhibited as strong an epizootic potential as standard strains. The speed of germination for large spored strains accounted for the greater epizootic potential of such strains. Khalil et al. (1983) studied effectiveness of V. lecanii to reduce population of aphids under glasshouse and field conditions. Test with V. lecanii against the aphid species Brachycaudus, Macrosiphoniella sanbornii and M. persicae on cucumber in glasshouse and Macrosiphum avenae

on wheat under modified field condition showed that the fungus was highly effective against these aphids at 25 ± 2 C and 100 per cent relative humidity. Control of M. persicae and M. avenae was rapid and reached 100 per cent in 25 days while that of M. sanbornii and Brachycaudus sp. was slower and took 30 and 35 days respectively to reach 100 per cent control. The fungus failed to control A. fabae on broadbean under field conditions.

Webber (1897) reported the importance of entomogenous fungi in control of various insects on citrus in Florida. Methods of distribution of Aschersonia aleyrodis Webber and Aegerita webberi Fawcett were also given. Forbes (1898, 1900) conducted experiments with Sphaerostilbe flammea Tul against Aspidiotus perniciosus Comst in Illinois and found that the fungus would serve as a highly effective agent in the destruction of the pest. Dupont (1913) reported methods of propagating the fungus Hypocrella sp. that attacked scale insects in Seychelles Quayle and Taylor (1915) attempted to use the fungus Isaria sp. for the control of Saissetia oleae (Bern) in California but it was not successful. Nolla (1929) reported that spore suspension of Acrostalagmus aphidum Qud when sprayed on the lower surface of eggplants infected with M. persicae killed the pest in 14 days in

Peurto Rico. Biard (1958) gave account of successful control of Sanjose scale Quadraspidiotus perniciosus in South California by Sphaerostilbe auranticola Petch.

Fusarium spp. as insect pathogen

The genus Fusarium taxonomically classified by Alexopoulos and Mims (1983) as coming under sub division Deuteromycotina, form class Deuteromycetinae, form sub class Hyphomycetidae, form order Moniliales and form family Tuberculariaceae. Fusarium typically produces two types of conidia that are terminal, viz. macro-conidia and micro-conidia because of their respective sizes. Both types are produced from phialides. Macroconidia are long multiseptate cresent or canoe shaped structures that are generally born on sporoddchia. Microconidia are one celled and spherically or ovally shaped. Most species of Fusarium are saprophytic or plant parasitic. But few species are found to cause insect diseases.

Kunckel d'Herculais and Langlois (1891) reported Fusarium acridiorum (Trabut) infection on desert locust Schistocerca gregaria (Forskl). Marchionatto (1933) recorded this pathogen on the eggs of S. paranenisis. Akbar et al. (1958) observed infection of eggs of S. gregaria also. Reinking (1921) found Fusarium epispheria, F. coccophila

as a parasite of scale insects on citrus in Philipines. Teodoro (1937) reported F. juruanum Hennings on coccids on coconut and F. parasiticum Fautrey on coccids on citrus from Philippines. Morqueer and Nystrakis (1944) reported Fusarium lateritium Champignon normally saprophytic on leaves became parasitic when it entered the galls of Phylloxera vitifoliae (Fitch). Steinhaus (1949) detected F. aleyrodis Petch (White fringe fungus) parasitic on Dialeurodes citri (R. and H.) and D. citrifolii (Morg.). Steinhaus and Marsh (1962) reported species of Fusarium attacking on Monochamus notatus (Drury), Coccus viridis, F. episphaeria on numerous scale insects, Fusarium species in Eurygaster pacifica Lattin., on the larvae of Chilo zonellus and larvae and pupae of Platynota rostrana Walker. Rachvelishrili (1965) reported that in Georgia pea aphid Macrosiphum pisum (Harris) was infected by Fusarium in addition to Entomophthora and Trichothecium. Madelin (1968) reported Fusarium citriculatum Montagne regularly associated with some of the cerambycid beetles. Live cerambycid larvae collected in the field was actively infected with the fungus. Gabriel (1968) reported infection of Fusarium episphaeria on Aonidiella aurantii, and Chrysomphalus aonidium and C. viridis. Viswanathan (1972) reported Fusarium oxysporum infection on

C. viridis. It was found very effective causing 100 per cent mortality within 15 days. Atwal et al. (1973) recorded Chilo partellus (Swinhoe) as a new host of Aspergillus flavus and Fusarium sp. Fusarium larvarum was the most widely spread parasitic species on Adelges piceae in Canada as reported by Smirnoff (1973). Popov and Illiesu (1975) reported Beauveria, Spicaria and Fusarium as the most important pathogens of Eurygaster integriceps. Sreedhar and Krishniah (1975) isolated Fusarium equisetii (Ida.) Sacc. from pupa and adults of Melanagromyza hibisci. Barson (1976) observed F. solani (Mart) as a weak pathogen of larval stages of the large elms bark beetle Scolytus scolytus. Kalvesh (1976) isolated Fusarium gibbosum var. bullattum, F. juvanicum, F. oxysporum, F. oxysporum var. orthoceras, F. sambueinum var. minus and F. semitectum from forest pests in Kulando. Kuruvilla (1979) reported comparative susceptibility of nymphs and adults of Nilaparvata lugens Stal to Fusarium oxysporum Schelt and its use in microbial control. Naseema Beevi (1982)areported Fusarium moniliformae var. subglutinans as pathogenic to the spotted beetle Epilachna vigintioctopunctata. Devanesan (1979) reported F. equisetii infecting Nephotetix viresens. Nayak and Sreevasthava (1978) reported F. oxysporum infecting Melanitis leda ismene

resulting in 80 to 90 percent mortality. Naseema Beevi (1978)a reported that F. moniliformae was pathogenic to Mylabris pustulata and Aulacophora species under laboratory condition. Nagalingam (1983) reported F. semitectum producing fungal epizootic in colonies of M. persicae. Raghavendra et al. (1987) reported that F. subglutinans was pathogenic to sugarcane scale insect Melanaspis glomerata (Green).

Giard (1891) reported that F. acridiorum (Trabut) formed a white powdery mass of greyish dawn on the surface of head, thorax, abdomen and hind feet of the desert locust Schistocerca gregaria. Reinking (1921) studied F. episphaeria and F. cocoophila infection on citrus scale and found that the fungus appeared red or pinkish with club shaped fruiting bodies on one edge only or more frequently from the entire margin of the scales. Steinhaus (1949) reported that a pinkish spore mass was found on the edge of Dialeurodes citri when infected with F. aleyrodis. Steinhaus and Marsh (1962) reported the symptoms of Fusarium infection on the larvae of Monochamus notatus. Reddish black spots appeared on thorax (later spreading) and white mycelium issuing from the cuticle at the infection site. The body tissue became translucent prior to the emergence of flocculant white mycelium. Atwal et al. (1973) reported that larvae of Chilo partellus infected with Fusarium sp. showed a swelling of the body and presence of necrotic interpleurite spots. The hyphal

covering on the body gave it a white appearance. Kuruvilla (1978) reported that when F. oxysporum infection was noticed on N. lugens the infected insects became sluggish, turned pale and later assumed a brownish colouration. Death occured within 24 - 78 hours of inoculation. Majority of insects dropped down after death while some were seen remaining attached to the plants. Towards death, there was a general softening of the body, but later on it got hardened. Growth of the mycelium on the cadavers was observed after 24 - 48 hours of death. The fungus produced both microconidia and macroconidia on the cadavers.

Moore (1973) studied B. bassiana, A. flavus and F. solani to southern pine beetle Dendroctonus frontalis at various temperature and humidity. Greater mortality occured in the temperature range of 15 - 20 C. Variation in temperature did not affect the mortality significantly. Nagalingam (1983) observed peak incidence of M. persicae and F. semitectum during October on cauli-flower, rainfall being the important requisite for the induction of fungal epizootic. Raghavendra et al. (1987) reported that for F. subglutinans a temperature regime of 15 - 20 C and relative humidity of 90 - 95 per cent appeared to be favourable to cause high mortality in sugarcane scale insect M. glomerata. Increase in temperature above 25 C and decrease in relative humidity

below 85 per cent showed decreasing trend in mortality.

Kuruvilla (1978) reported F. oxysporum when applied at 6.25 x 10^6 spores per ml on N. lugens caused 100 per cent mortality within three days. The first and second instar nymphs were more susceptible than third, fourth and fifth instar nymphs and adults. Raghavendra (1987) reported that F. subglutinans when sprayed at higher doses of 10^7 - 10^9 spores per ml on sugarcane scale insect caused about 60 per cent mortality of first and second instar nymphs. Mortality ranged from 36.7 - 53.7 and 48.5 - 54.9 per cent at 10^3 - 10^6 spores per ml in first and second instars respectively.

Lack of adequate quantities of pathogen has been a serious impedement towards the development and application of microbial control agent in plant protection programme. Kuruvilla et al. (1979) attempted mass production of F. oxysporum on greengram, wheat, sorghum, ragi and redgram. Though all the media gave good growth and sporulation, greengram and wheat appeared to be the most suitable as they produced maximum spores with high virulence. For the mass production of F. semitectum [illegible]en maize grain and blackgram husk or redgram husk at [illegible] (w/w) was reported by Nagalingam (1983). Raghavendra et [illegible] 1987) masscultured

F. subglutinans on moist sterile sorghum grains. Three week old culture was used by which time the fungus sporulated abundantly.

Kuruvilla (1978) reported F. oxysporum as nonpathogenic to crops viz. cotton, rice and tomato. Naseema Beevi (1982)b reported that F. moniliformae was safe to cotton, tomato, bittergourd, brinjal and snakegourd. Nagalingam (1983) observed that F. semitectum was safe to all instars of mulberry silkworm, adult honeybee, hymenopterous parasitoids and coccinellid predators. The fungus was also reported as safe to plants like chillies, cabbage, brinjal and tobacco.

MATERIALS AND METHODS

MATERIALS AND METHODS

Raising of Cowpea crop

Cowpea crop (Var. C152) was raised at monthly intervals in an area of 50m^2 in the Instructional Farm, Vellayani. Spacing, application of manures and fertilizers and cultural operations were adopted as per package of practices recommendations of Kerala Agricultural University (1983).

Observations of population fluctuation of peaaphid *Aphis craccivora* Koch. and its predators.

Observations on population of aphids and predators were recorded from each plot from the fourth week after planting. Eight observations were recorded at weekly intervals from each planting. Each observation was taken from ten plants selected at random. Unit area taken for observation was seven cm from the tip of the branch including the leaves and pods in that area. Aphid infestation was grouped into various classes following the method of Banks (1954).

Class		Description
Zero	(0)	Where there was no aphid present.
Very light	(V)	Where there was one aphid to a small colony of some scattered individuals confined to young leaves.
Light	(L)	Where there were scattered aphid colonies present in the stem and leaves and not confined to crown and upper leaves.

Medium (M) Aphid present in large numbers not in recognisable colonies but defuse and infesting a large proportion of stem and leaves.

Heavy (H) Aphid present in very large numbers, very dense, infesting all the leaves and stem usually black with aphid.

Number of aphids for each class was found out by counting ten samples from each class and taking average of it. The samples were picked up from the field carefully without causing any disturbance to aphid colonies and kept sealed in individual labelled bottles containing 95 per cent ethanol and counting done later. Before counting each sample, aphids were dislodged from the leaves and stem by slow agitation of it in the alcohol with the use of a camel hair brush. From the sample containing the dislodged aphids a small portion was taken with an ordinary aspirator and transferred to a petri dish. A graph paper was pasted at the bottom of the petri dish. When all aphids settled in the petri dish excess alcohol was carefully drained with the aspirator so that the aphids did not move while counting. Counting was done under stereo microscope. All the aphids in each sample were counted. Ten samples were counted from each class and the average of each class was worked out as follows.

Classes of pea aphid population

Class		Number of aphids per sample										Mean
		1	2	3	4	5	6	7	8	9	10	
Very light	(V)	2	5	1	7	3	1	5	7	8	4	4.3
Light	(L)	49	78	63	108	97	84	63	46	54	77	71.9
Medium	(M)	171	210	205	164	204	114	240	127	180	161	192.6
High	(H)	304	470	535	405	440	369	478	570	520	496	458.7

The populations of predators were recorded from ten plants for each observation by direct counting of immature stages and adults.

Weather data

The meteorological data included in the study were obtained from the Instructional Farm, College of Agriculture, Vellayani. Data on maximum and minimum temperature, relative humidity and rainfall recorded at 8 am were collected every day and the weekly averages worked out.

Population fluctuation due to month of planting and stage of crop

Data on the population fluctuation of the aphid during different months of planting from October 1984 to September 1985 and fluctuation of population of aphids and its predators during different stages of crop were statistically analysed.

Correlation studies

With a view to study the influence of weather factors and predators on aphid population, the data obtained were statistically analysed. Simple correlation between aphid population during different stages of the crop and climatic factors and predators wase also worked out. A multiple regression equation was also fitted to the aphid population with predator population and physical parameters.

Sterilization of glassware

All glassware, viz., petri dishes, conical flasks, test tubes etc. were kept for 24 hours in cleaning solution containing 60 g potassium dichromate and 60 ml concentrated sulphuric acid in one litre of water. They were then washed well in tap water and rinsed in distilled water and air dried. All the glassware were then sterilized in a hot air oven at 160 C for two hours. Pipettes and measuring cylinders were autoclaved at 15 psi for 20 minutes.

Preparation of media

Following media were used in the experiments.

Potato dextrose agar:

Peeled potato	-	200.00 g
Dextrose	-	20.00 g
Agar	-	20.00 g
Distilled water	-	1000.00 ml

Two hundred grams of peeled potato were sliced into small pieces and boiled in one litre of distilled water for one hour. The potato pieces were filtered out and 20 g of dextrose and 20 g of agar were added to the filtrate, the volume was made up to 1000 ml and it was sterilized at 15 psi for 20 minutes. The pH of the medium was adjusted to seven before sterilization using an indicator paper.

Czapek (Dox) agar:

Sodium nitrate ($NaNo_3$)	-	2.00 g
Potassium dihydrogen phosphate (KH_2PO_4)	-	1.00 g
Magnesium sulphate ($MgSo_4 7H_2O$)	-	0.50 g
Potassium cloride (Kcl)	-	0.50 g
Ferrous sulphate ($FeSo_4 7H_2O$)	-	0.01 g
Sucrose	-	30.00 g
Agar	-	20.00 g
Distilled water	-	1000.00 ml

Twenty grams of agar was boiled in one litre of distilled water and the above ingredients were dissolved in it. pH of the medium was adjusted to seven. It was transferred to sterilized Ehrlenmayer flasks (250 ml) at the rate of 100 ml per flask, wrapped with paper and autoclaved for 20 minutes at 15 psi.

Richards' agar:

Potassium nitrate (KNO_3)	-	10.00 g
Potassium dihydrogen phosphate (KH_2PO_4)	-	5.00 g
Magnesium sulphate ($MgSo_4 7H_2O$)	-	2.50 g
Ferric chloride ($FeCl_3$)	-	0.02 g
Sucrose	-	50.00 g
Agar	-	20.00 g
Distilled water	-	1000.00 ml

The medium was prepared as detailed above in the case of Czapek (Dox) agar.

Sabouraud dextrose agar:

Dextrose	-	40.00 g
Peptone	-	10.00 g
Agar	-	20.00 g
Distilled water	-	1000.00 ml

The ingredients were mixed well and boiled till dissolved. The pH was adjusted to 5.6 and sterilized at 15 psi for 10 minutes.

Preparation of slants and plates

Three to five ml of the prepared media were poured into clean test tubes and plugged with cotton. They were then sterilized at 15 psi for 20 minutes. The slants were prepared by placing the tubes in a slanting position and allowing the media to solidify.

In the preparation of plates 15 ml of sterilised medium at 42° C was poured into sterile petri dish. The covered petri dishes were gently rotated to aid in the even distribution of medium over the bottom of the dish. The medium was then allowed to solidify.

Survey of fungal pathogens of peaaphid

The cowpea crop in the experimental plots and the crop raised in the Instructional Farm, Vellayani and adjoining farmers fields were surveyed for disease

incidence among aphid population. Dead or dying aphids both adults and nymphs suspected to be infected were periodically collected and the associated fungi if any were isolated.

Isolation of pathogen from peaaphid

Dead and dying adults and nymphs of peaaphid suspected to be infected with fungi were surface sterilised with 0.1 per cent mercuric chloride in 75 per cent ethyl alcohol for one to two minutes, washed in three changes of sterile water and placed in sterile petri dishes containing potato dextrose medium and incubated at room temperature. After 24 hours when growth of the fungus was visible to naked eye, bits of mycelial tips were transferred to potato dextrose agar slant and maintained in pure culture for further studies.

Pathogenicity tests for fungal isolates

The disease free laboratory culture of peaaphid A craccivora maintained in the insectary on potted cowpea plants were used for pathogenicity studies. Each potted plant with the aphid colony was confined in glass chimney. The fungal isolates were applied on the aphid colonies to test its pathogenicity. Out of three isolates, Koch's postulates were established in the case of one isolate only and it was sent to Commonwealth Mycological Institute,

London for identification. A pure culture of this fungus was maintained in the laboratory and all further studies were conducted using this fungus.

Maintenance of culture of Fusarium pallidoroseum (Cooke) Sacc.

The fungus was initially cultured on potato dextrose agar but subsequently maintained on Sabouraud dextrose agar medium since it was found more suitable for growth of the pathogen. The virulence of the fungus was maintained by periodically culturing in the host insect A craccivora.

Preparation of slide culture for morphological studies

Ten ml of molten agar medium was poured into a sterile petri dish. After solidification the plate was marked into one cm squares using a sterile dissection needle. The agar square was lifted out and placed on a sterile microscope slide kept inside a sterile petri dish. Fungal spores were inoculated on two edges of the square and covered with a sterile cover slip. Slide culture was then transferred to moist chamber containing small amount of 20 per cent glycerine to prevent foggying. Glass rods with ends bend were placed in the petri dish and the slides were supported thereon to prevent them from getting wet. The cultures were periodically checked for growth and sporulation. After 48 hours two permanent slides each were

prepared from a slide culture as follows. The cover slip was removed from the agar block and applied a drop of lactophenol containing cotton blue and the cover slip was gently lowered on a clean slide. Similarly the original slide with the fungus grown on it was covered with a clean cover slip after adding a drop of lactophenol containing cotton blue. Fungal growth was observed microscopically and photomicrographs were taken.

Measurement of conidia

A drop of dilute spore suspension in sterile water was placed on a clean glass slide and covered with a cover slip. Length and breadth of conidia were measured under microscope using a calibrated ocular micrometer.

Effect of different media on growth of F. pallidoroseum

Plates were poured with four different media, viz., potato dextrose agar, Richards' agar, Czapek (Dox) agar and Sabouraud dextrose agar as described earlier. One loop full of the inoculum prepared as explained above was placed in the centre of each plate. The same stock inoculum was used for all petri dishes. The petri dishes were inoculated at room temperature. Each treatment was replicated four times. Radial growth of the fungus was recorded from the third day onwards till growth of the fungus in any of the media completely covered the petri dish.

Effect of age of culture on sporulation

Thirty two plates each with four media, viz. potato dextrose agar, Richards' agar, Czapek (Dox) agar and Sabouraud dextrose agar were inoculated with the fungus as explained earlier. Starting from second day onwards sporulation of four plates from each medium was observed daily up to ninth day for spore count. Five mm diameter discs were cut out from three different areas of the petri dish and were put into 250 ml conical flask containing 100 ml sterile water. The flask was agitated thoroughly. After suitable serial dilution spore counts were recorded under a binocular research microscope using a double ruled Neubauer haemocytometer.

Effect of different media on virulence of the pathogen

Slants were prepared with the four media, viz., potato dextrose agar, Richards' agar, Czapek (Dox) agar and Sabouraud dextrose agar and inoculated with the fungus as explained earlier. They were allowed to grow for nine days. Five ml of sterile distilled water was poured into the nine day old culture slants. After shaking the tubes well the resulting suspension was transferred to empty sterile test tube and the concentration was standardised to 3.5×10^6 spores per ml. The test insects were drawn from disease free culture of peaaphid maintained in the

insectary. Adult wingless peaaphids were used for the experiment. Two ml of the fungal spore suspension was applied on the aphids with an atomiser and the same were released on immature pods kept in sterile petri dishes. The experiment was replicated four times. Insect mortality was recorded every day up to fourth day for each medium.

Effect of age of culture on virulence of pathogen

Slants were prepared with Sabouraud dextrose agar media and inoculated with F. pallidoroseum. Starting from third day onwards till ninth day spore suspensions were prepared as explained above. The pathogenicity of the spore suspension for each day was assayed against adult wingless peaaphids at a uniform concentration of 3.5×10^6 spores per ml. The experiment was replicated four times. The mortality of peaaphid was recorded everyday till the fourth day and the data from cumulative mortality was statistically analysed.

Selection of suitable medium for mass culture of the pathogen

In order to find out a suitable medium for mass culture of the fungus preliminary trials were conducted with the following materials.

1. Rice grain
2. Wheat grain

3. Ragi grain
4. Maize grain
5. Cowpea
6. Greengram
7. Jack seed
8. Coconut oil cake
9. Tapioca chips
10. Paddy straw

Thirty g each of the above materials were taken in seperate 250 ml conical flasks containing 30 ml of distilled water and plugged with cotton. Flasks were then autoclaved at 15 psi for 20 minutes. Discs were cut from outer edge of seven day old cultures by means of a sterile cork borer and transferred into conical flasks containing the materials. The flasks were shaken well in order to disperse the inoculum and then incubated at room temperature. Growth of fungus was observed daily.

Following media which gave satisfactory growth of the fungus in the preliminary test was selected for further studies.

1. Rice grain
2. Wheat grain
3. Ragi grain

4. Maize grain
5. Jack seed
6. Coconut oil cake
7. Tapioca chips

Sporulation of the fungus in the above materials was recorded on the ninth day. Each treatment was replicated five times.

Pathogenicity of F. pallidoreseum to certain crop plants

Pathogenicity of the fungus to rice, bhindi, brinjal, chillies and tomato were assessed by three methods of inoculation as detailed below. Observations were made daily on the condition of the plants till harvest.

(i) Soil inoculation

Earthen pots of 10 cm diameter were filled with potting mixture (wet soil in the case of rice) and the surface soil was mixed with 25 ml of spore suspension at a concentration of 7×10^6 spores per ml. Four pots were prepared for each crop. Planting of the seedlings was done after two hours at the rate of one seedling per pot. Soil mixed with 25 ml of sterile water alone served as control.

(ii) Seed inoculation

25 g each of the seeds were thoroughly cleaned to remove all the foreign materials and well dried in sunlight.

The seeds were then soaked in 10 ml of spore suspension and kept for 24 hours. Seeds soaked in sterile water served as control. Treated seeds were sown in pots. The experiment was replicated four times for each crop.

(iii) Leaf inoculation

One month old healthy plants were used for this inoculation. Injury was made on leaf by pin pricks. Inoculation was done with culture bits by placing them on injured spots and covered with moist cotton wool. Injured spots covered with moist cotton wool alone was kept as control. Four leaves were treated in each plant and there were four replications in each.

Saftey of fungus F. pallidoroseum to grubs of Menochilus sexmaculata

Second instar grubs of M. sexmaculata reared in the laboratory were used in the experiment. Ten grubs were taken in a petri dish and a fungal spore suspension containing 7×10^6 spores per ml was sprayed on them using an atomizer. A control was also maintained. The grubs were then reared individually in specimen tubes till adulthood. The treated grubs were daily observed for occurrence of fungal infection.

Bioassay of F. pallidoroseum against peaaphid A. craccivora

The test insects were drawn from disease free culture

of peaaphid. Five serial dilutions of the fungal spore suspensions, as follows, were prepared from the stock solution of seven day old fungus grown in Sabouraud dextrose agar media.

(i) 7.0000×10^6 spores per ml

(ii) 3.5000×10^6 spores per ml

(iii) 1.7500×10^6 spores per ml

(iv) 0.8750×10^6 spores per ml

(v) 0.4375×10^6 spores per ml

Two ml of fungal spore suspension was applied on the aphid with an atomizer and the same were released on immature pods kept in sterile petri dish. The experiment was replicated four times. Aphids similarly treated with distilled water alone served as control. Observations on insect mortality were recorded everyday. The log dose probit mortality data was statistically analysed and Lc50 worked out.

Control of peaaphid A. craccivora with F. pallidoroseum

An experiment was conducted to test the efficacy of F. pallidoroseum against peaaphid A. craccivora under field conditions. The experiment was laid out in a randomised block design with five treatments and five replications. The treatments were as follows:

T_1 - 1.75×10^6 spores per ml

T_2 - 3.50×10^6 spores per ml

T_3 - 7.00×10^6 spores per ml

T_4 - 0.05%Quinalphos

T_5 - Control

Cowpea variety C152 was raised during November 1985 in the Instructional Farm, Vellayani. All cultural operations were carried out according to package of practices recommendations of Kerala Agricultural University (1983). Pretreatment observations on the population of the aphids and predators were recorded from 10 plants in each plot. Treatments were applied in the evening along with Teepol 0.01 per cent after an irrigation. Control plot received a spray with distilled water mixed with Teepol 0.01 per cent. The treatments were applied on the eighth week after sowing when there was sufficient population build up of aphids in all test plots. The change in population of aphids and predators after treatment was observed seven days after application of the treatments. The data obtained were statistically analysed.

RESULTS

RESULTS

Population fluctuation of pea aphid, *Aphis craccivora* Koch. in relation to time of planting and stage of crop

The observation on the population of pea aphid *A. craccivora* recorded from the monthly plantings of the pulse crop from October 1984 to September 1985 are furnished in Table 1. Maximum population of pea aphids was observed (Mean 249.78) in the crop planted in November and it was significantly higher than the population in all other months of planting. The crop planted in October recorded the next higher mean population of 165.62 followed by the plantings in December and August with a mean population of 154.25 and 139.52 aphids respectively. There was no significant difference in the population recorded for these three plantings. The lowest mean population of 1.47 aphids was recorded in the crop planted during the month of March. The population trend in the various plantings is illustrated in Fig. 1.

It can also be seen from the results presented in Table 1 that the population of peaaaphids was very much influenced by the stage of the crop. The maximum incidence of aphids was observed during the eighth week of the crop with a mean population of 145.04 aphids followed by ninth

Table 1. Population of pea aphid A. craccivora observed on cowpea in relation to time of planting and growth stages of the crop

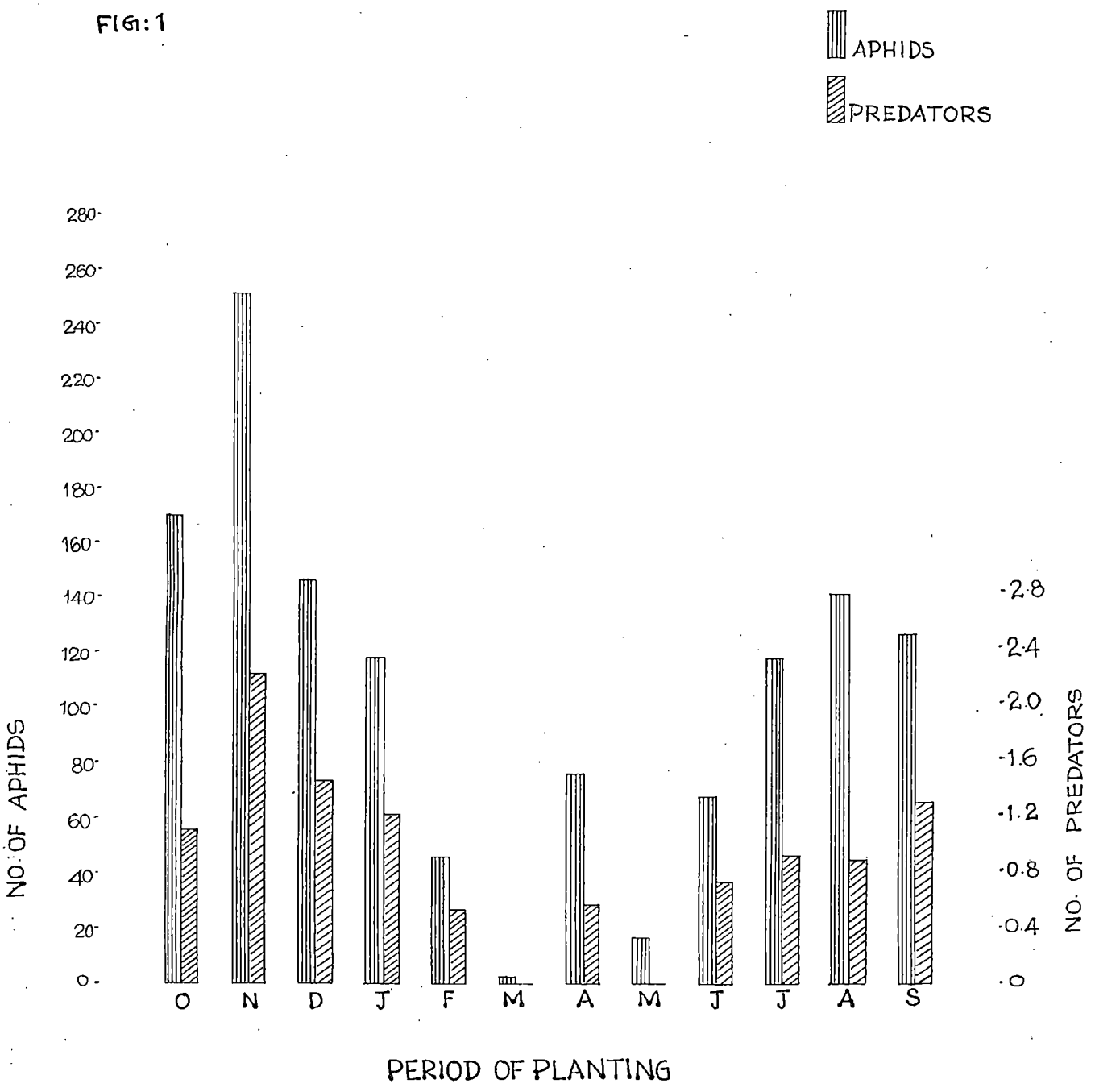
Planting time	Mean number of aphids observed at different intervals after planting (weeks)								Mean
	4	5	6	7	8	9	10	11	
October 1984	4.78	135.37	163.84	243.43	326.88	240.09	195.61	169.40	165.62
	(2.40)	(11.68)	(12.84)	(15.63)	(18.11)	(15.53)	(14.02)	(13.05)	(12.91)
November 1984	83.29	189.62	220.47	311.49	426.99	426.99	285.45	163.85	249.78
	(9.18)	(13.81)	(14.88)	(17.68)	(20.69)	(20.69)	(16.92)	(12.84)	(15.84)
December 1984	42.31	198.63	226.91	236.76	220.47	175.07	125.03	81.37	154.25
	(6.58)	(14.13)	(15.10)	(15.42)	(14.88)	(13.27)	(11.22)	(9.07)	(12.46)
January 1985	50.91	169.40	189.62	214.11	189.62	129.90	78.28	16.41	117.42
	(7.20)	(13.05)	(13.81)	(14.67)	(13.81)	(11.44)	(8.90)	(4.17)	(10.88)
February 1985	42.31	150.32	150.32	125.03	20.77	4.17	3.60	0.59	42.48
	(6.58)	(12.30)	(12.30)	(11.23)	(4.67)	(2.27)	(2.14)	(1.26)	(6.59)
March 1985	0.00	0.00	0.93	3.06	8.17	0.27	0.27	2.55	1.47
	(1.00)	(1.00)	(1.39)	(2.01)	(3.02)	(1.13)	(1.13)	(1.88)	(1.57)
April 1985	0.27	6.66	20.77	70.44	155.66	189.62	243.43	137.38	77.18
	(1.13)	(2.77)	(4.67)	(8.45)	(12.52)	(13.81)	(15.63)	(11.76)	(8.84)
May 1985	3.60	41.73	60.29	60.29	15.34	8.17	0.00	0.00	16.44
	(2.14)	(6.54)	(7.83)	(7.83)	(4.04)	(3.03)	(1.00)	(1.00)	(4.18)
June 1985	0.00	0.00	3.06	26.08	138.40	229.77	260.53	117.87	65.50
	(1.00)	(1.00)	(2.01)	(5.20)	(11.81)	(17.14)	(16.17)	(10.90)	(8.16)
July 1985	8.18	68.99	204.76	220.47	150.29	183.70	175.04	39.51	114.95
	(3.02)	(8.37)	(14.34)	(14.88)	(12.30)	(13.59)	(13.27)	(6.37)	(10.77)
August 1985	11.40	53.90	199.24	250.21	250.21	250.21	210.97	57.62	139.52
	(3.52)	(7.40)	(14.15)	(15.85)	(15.85)	(15.85)	(14.56)	(7.66)	(11.85)
Septumber 1985	1.31	44.26	106.87	158.91	175.07	243.43	226.91	214.74	125.47
	(1.52)	(6.73)	(10.39)	(12.65)	(13.27)	(15.63)	(15.09)	(14.69)	(11.25)
Mean	13.25	66.73	105.27	138.15	145.04	141.70	116.51	61.16	
	(3.77)	(8.23)	(10.31)	(11.80)	(12.08)	(11.95)	(10.84)	(7.88)	

C.D. for comparing the population on cowpea planted at different months = 1.78

C.D. for comparing the population at different growth stages of cowpea = 0.96

POPULATION OF APHIDS AND ITS PREDATORS
IN THE CROP PLANTED IN DIFFERENT MONTHS

FIG: 1



week and seventh week with a mean aphid population of 141.70 and 138.15 respectively. The population recorded during these three weeks were on par with each other. The lowest population of 13.25 aphids was observed during the fourth week. The population showed an increasing trend upto eighth week and decreased thereafter (Fig. 2).

Population fluctuation of predators of pea aphid

The results presented in Table 2 show significant fluctuation in the population of predators during different months of planting and during different stages of crop. Maximum population of predators was recorded in November planted crop with a mean population of 2.24 predators. Predators were not recorded in the crop planted during March and May. Maximum population of predators was recorded during the eighth week of the crop (Mean 1.43). Least population was recorded during fourth week of the crop, the mean being 0.09. The density dependent nature of the population of predators in different months of planting and at different stages of the crop is depicted in Fig. 1 and 2.

Population fluctuation of pea aphid in relation to weather factors and predators

Observation on the population of pea aphid collected

POPULATION OF APHIDS AND ITS PREDATORS AT DIFFERENT GROWTH STAGES OF COWPEA

FIG 2

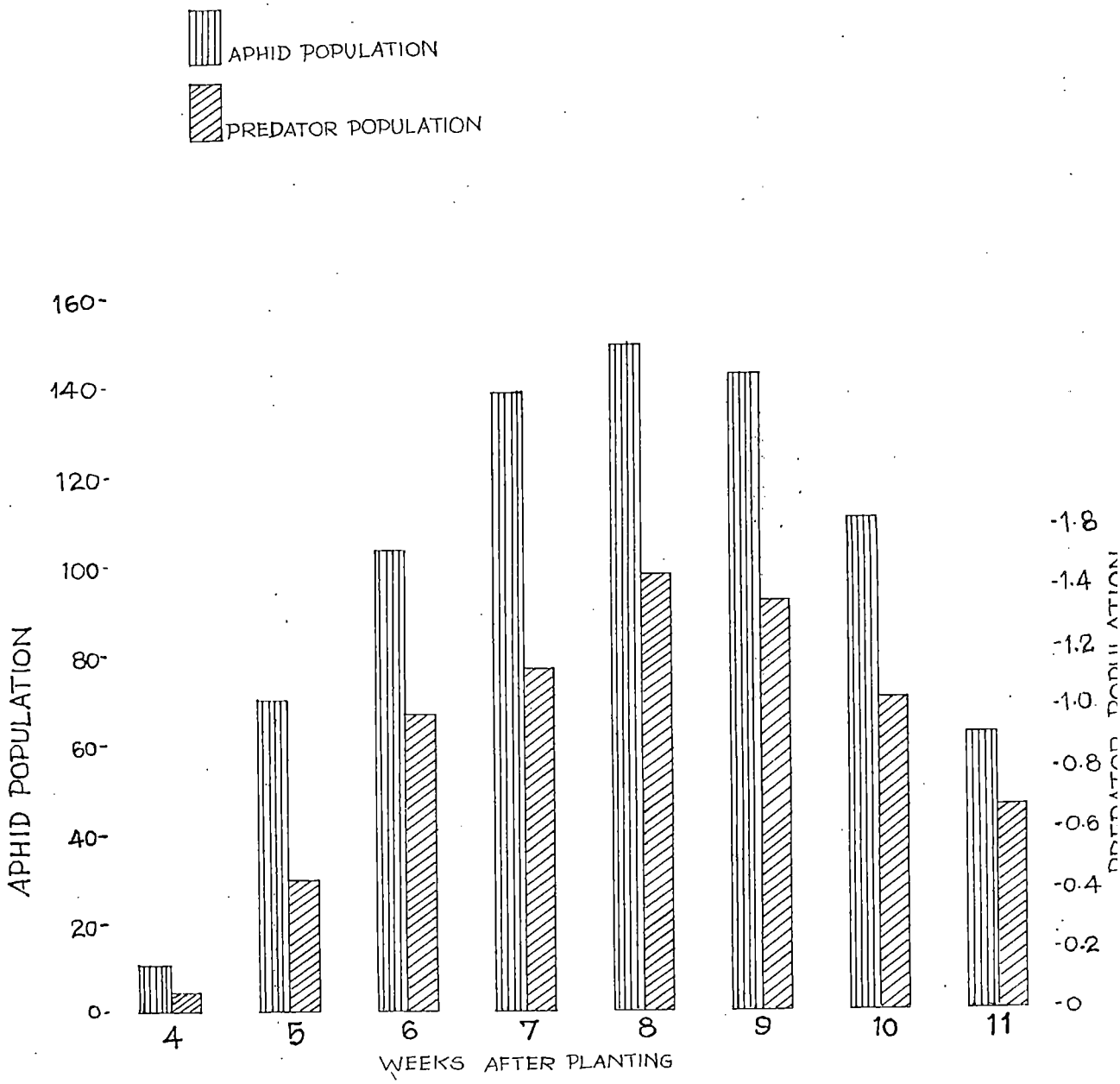


Table 2. Population of predators of pea aphid A. craccivora observed on cowpea

Planting time		Mean number of predators observed at different intervals after planting (weeks)								Mean
		4	5	6	7	8	9	10	11	
October	1984	0.152 (1.073)	0.994 (1.412)	1.483 (1.576)	1.399 (1.549)	1.597 (1.611)	1.214 (1.488)	1.429 (1.559)	1.240 (1.497)	1.164 (1.471)
November	1984	0.210 (1.100)	1.368 (1.539)	1.615 (1.617)	3.039 (2.010)	4.229 (2.287)	3.865 (2.206)	2.813 (1.953)	1.857 (1.690)	2.240 (1.800)
December	1984	0.000 (1.000)	0.905 (1.380)	2.265 (1.808)	2.850 (1.962)	2.455 (1.859)	2.237 (1.799)	1.368 (1.539)	0.399 (1.183)	1.452 (1.566)
January	1985	0.085 (1.041)	1.411 (1.553)	1.721 (1.650)	2.232 (1.798)	2.920 (1.980)	1.368 (1.539)	0.557 (1.248)	0.151 (1.073)	1.205 (1.485)
February	1985	0.709 (1.307)	0.709 (1.307)	1.381 (1.543)	0.903 (1.380)	0.434 (1.198)	0.303 (1.414)	0.085 (1.041)	0.000 (1.000)	0.538 (1.240)
March	1985	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)
April	1985	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.720 (1.311)	1.262 (1.509)	1.915 (1.703)	1.221 (1.490)	0.567 (1.252)
May	1985	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)
June	1985	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	1.206 (1.485)	2.156 (1.777)	2.168 (1.780)	0.926 (1.388)	0.700 (1.304)
July	1985	0.000 (1.000)	0.000 (1.000)	1.858 (1.691)	1.870 (1.694)	1.339 (1.529)	1.301 (1.517)	1.113 (1.454)	0.839 (1.356)	0.974 (1.405)
August	1985	0.000 (1.000)	0.336 (1.156)	1.411 (1.552)	1.411 (1.552)	2.220 (1.795)	2.053 (1.747)	0.359 (1.166)	0.359 (1.166)	0.938 (1.392)
September	1985	0.000 (1.000)	0.000 (1.000)	1.284 (1.511)	1.742 (1.656)	1.474 (1.573)	2.404 (1.845)	2.404 (1.845)	2.156 (1.777)	1.360 (1.536)
Mean		0.089 (1.043)	0.429 (1.196)	0.995 (1.412)	1.154 (1.467)	1.431 (1.559)	1.393 (1.547)	1.076 (1.441)	0.694 (1.302)	

C.D. for comparing the population during different months of planting = 0.081

C.D. for comparing the population during different stages of the crop = 0.009

for a period of one year from November 1984 and December 1985 are furnished in Annexure I and population of predators of aphids for the corresponding period in Annexure II. Correlations have been worked out between the population of pea aphids, its predators and weather factors. The results are furnished in Table 3. It can be seen from the results that there is significant positive correlation between population of aphid and relative humidity. The population of predators of aphids is significantly positively correlated with relative humidity. Rainfall is negatively correlated with population of aphids. Other weather factors such as maximum and minimum temperature had a negative correlation with aphid population. The results also showed a highly significant positive correlation between population of aphids and its predators. (Fig. 3)

The results presented in Table 4 show the correlation of weather factors and predators on the population fluctuation of pea aphid during different stages of the crop. A positive correlation between aphid population and predator population is noticed except during the fourth week of the crop. Relative humidity was also found to be positively correlated with aphid population.

Multiple regression equation was fitted to the aphid

Table 3. Correlation between weather parameters, predator population and fluctuating population of A. craccivora on cowpea during 1984-85.

Parameters (x)	x_1	x_2	x_3	x_4	x_5	Aphid population
x_1 Maximum temperature		0.2366	-0.0064	-0.5558	-0.1077	-0.1460
x_2 Minimum temperature			0.2561	-0.0901	-0.0462	-0.0760
x_3 Relative humidity				-0.1030	0.3430*	0.4297*
x_4 Rainfall					0.0118	-0.0260
x_5 Predators						0.9004*

* Significant at 5% level

POPULATION FLUCTUATION OF A. CRACCIVORA

IN RELATION TO PREDATORS AND WEATHER FACTORS

FIG 3

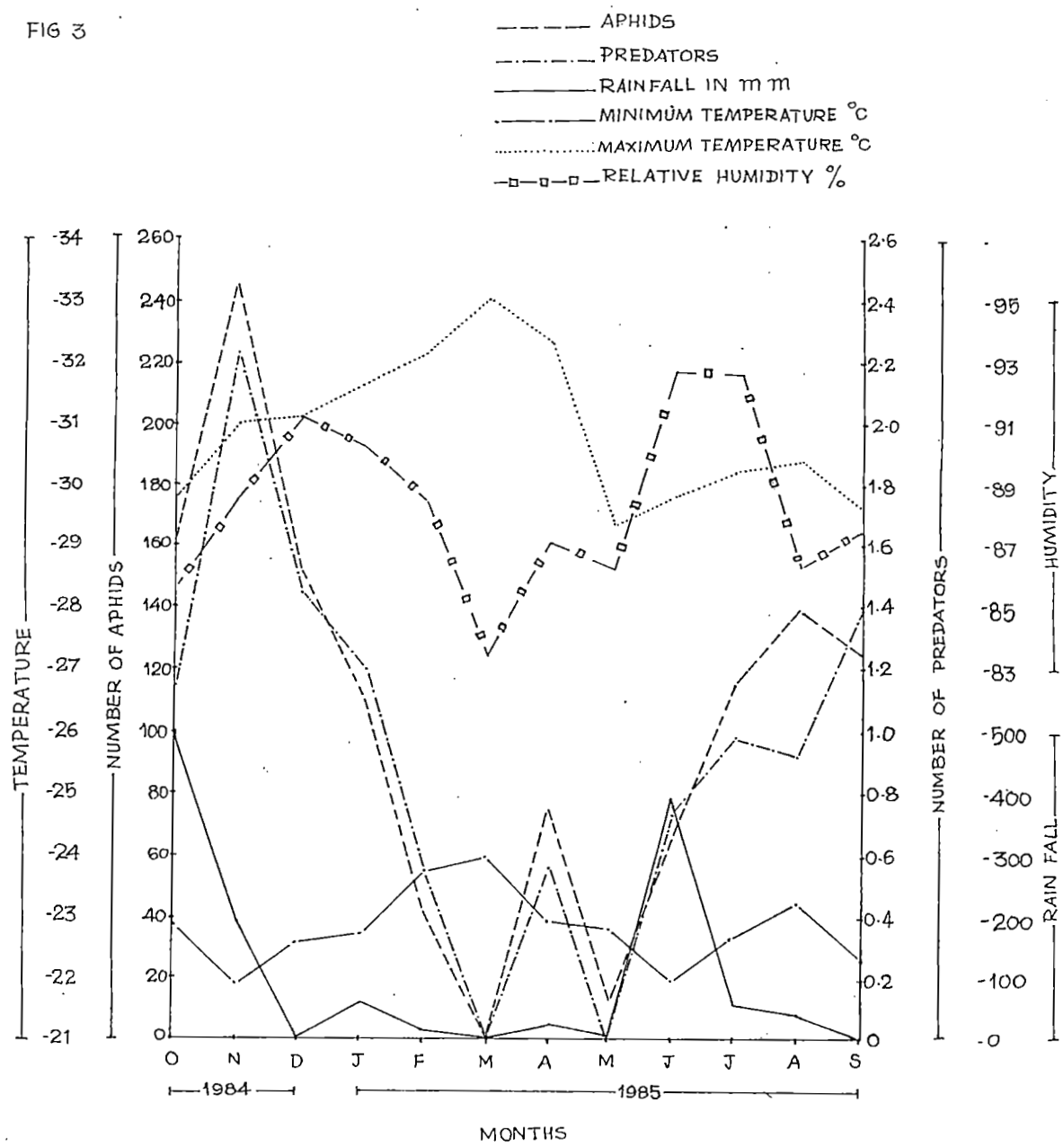


Table 4. Correlation between weather factors, predator population and population of A. craccivora on cowpea during different stages of the crop

Parameters	Correlation at different intervals after planting (in weeks)							
	4	5	6	7	8	9	10	11
Maximum temperature	0.1329	0.2963	0.1314	-0.0152	-0.3623	-0.3922	-0.3367	-0.2877
Minimum temperature	0.2500	-0.0369	0.1274	-0.2897	0.0862	0.1309	0.3811	-0.4119
Relative humidity	0.5545	0.4894	0.5838*	0.0440	0.5060	0.6690	0.6598	0.2671
Rainfall	-0.2899	-0.4514	-0.4321	-0.2664	0.2886	0.1077	0.1781	-0.1949
Predators	-0.0851	0.9098*	0.9362*	0. 834*	0.8417*	0.8807*	0.9305*	0.9655*

* Significant at 5% level

population with weather parameters and population of predators(Table 5). Eighty four per cent of variation of population could be accounted by the variables under study. Partial regression coefficient of the aphid and relative humidity was found to be positive and significant. Among the other weather parameters, maximum temperature had a significant negative partial regression coefficient. Partial regression coefficient of the aphid with minimum temperature and rainfall was negative but not significant. The partial regression coefficient between aphid population and predator population was positive and highly significant.

Survey of fungal pathogens

A survey was conducted in the Instructional Farm, College of Agriculture, Vellayani and in the adjucent farmers fields to collect fungal pathogens associated with pea aphids. Three fungal isolates were obtained of which only one was found to be pathogenic to the pea aphid in the preliminary laboratory studies. Koch's postulates were established in this case. The fungal isolate was identified as Fusarium pallidoroseum (Cooke) Sacc. by the Common Wealth Mycological Institute, Kew, England. Further studies were taken up with this pathogen.

Table 5. Results of multiple regression analysis of predators and weather factors on aphid population

Multiple regression equation

$Y = 80.760 + 89.545\ X_1 + 8.942\ X_2 - 5.623\ X_3 + 4.168\ X_4 - 0.189$

Variables		(b)value	SE	Computed 't'
Predators	X_1	89.545	4.780	18.730*
Maximum temperature	X_2	-8.942	4.467	-2.001*
Minimum temperature	X_3	-5.623	4.800	-1.171
Relative humidity	X_4	4.168	1.311	3.177*
Rainfall	X_5	-0.189	0.121	-1.560

* Significant at 5 % level

$R^2 = 84.48\%$

Symptomatology

The infected insects turned pale in the initial stages and assumed a brownish black discolouration later on. Complete mortality of the pea aphid occurred in 48 to 72 hours of inoculation. The mummified cadavers were seen firmly adhered to the plant (Plate I). The dead insects were hard to touch, external mycelial growth appeared in 24 to 48 hours after death. The dead insects were covered by a fluffy white mycelial growth of the fungus in 72 hours (Plate II).

Morphological characters of *Fusarium pallidoroseum* (Cooke) Sacc.

Characteristics of the fungus observed when cultured on Sabouraud dextrose agar medium were as follows. Mycelium septate, aerial mycelium slightly peach coloured to white, hypha elongate, separate and branched (Plate III). Conidia produced in aerial mycelia and were 1 to 7 septate. Conidia were spindle shaped or sickle shaped tapering at both ends. (Plate IV).

The average size of the conidia were as follows:

1	septate	5 - 17 µ x 2.0 - 3.7 µ
2-3	septate	9 - 23 µ x 2.0 - 4.5 µ
3-5	septate	27 - 41 µ x 3.5 - 5.5 µ
5-7	septate	38 - 57 µ x 3.7 - 5.4 µ

Plate No. 1 Pea aphid killed by F. pallidoroseum remaining attached to the plant.

Plate No. 2 *F. pallidoroseum* growing from cadaver of pea aphid.

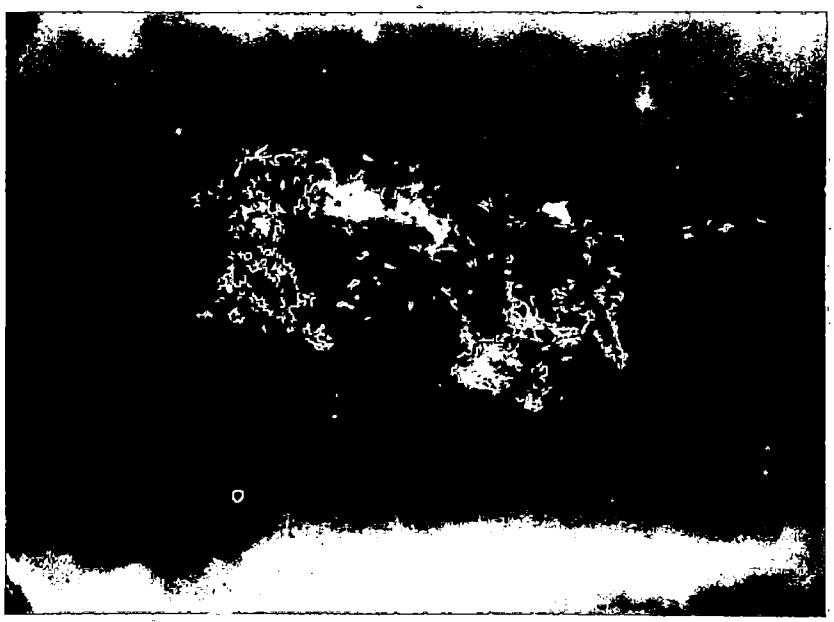


Plate No. 3 Mycelium of *F. pallidoroseum*

Plate No. 4 Conidia of F. pallidoroseum

Effect of media on growth of the fungus F. pallidoroseum

The effect of different artificial media on the growth of the fungus is presented in Table 6. Maximum mean radial growth of 61.30 mm observed on Sabouraud dextrose agar medium was statistically superior to all other media used. The next best was potato dextrose agar medium with a mean radial growth of 49.54 mm.

The highest radial growth was recorded on the ninth day with a mean growth of 82.16 mm followed by eighth day. There was significant increase in the radial growth of the fungus from third to seventh day. However, growth recorded on eighth and ninth day were on par with each other. The results are illustrated in Fig.4.

Effect of different media on sporulation of the fungus F. pallidoroseum

The influence of composition of media on sporulation of the fungus is presented in Table 7 and illustrated in Fig. . The sporulation on Sabouraud dextrose agar medium was found to be significantly higher with a mean of 4.04×10^6. It was followed by potato dextrose agar medium (Mean 3.18×10^6).

The comparison between period showed maximum sporulation

Media used	Mean diameter of colony (in mm) observed at different intervals after inoculation (days)							
	3	4	5	6	7	8	9	Mean
Potato dextrose agar	17.87 (1.2520)	30.90 (1.4897)	39.82 (1.6251)	49.47 (1.6941)	60.57 (1.7820)	68.42 (1.8352)	79.72 (1.9013)	49.54 (1.6542)
Czapek (Dox) agar	11.32 (1.0538)	18.12 (1.2574)	30.12 (1.4780)	35.17 (1.5506)	46.87 (1.6704)	55.28 (1.7416)	74.72 (1.8735)	38.80 (1.5179)
Richards' agar	12.15 (1.0833)	22.07 (1.2421)	41.92 (1.6273)	48.97 (1.6898)	60.85 (1.7840)	77.12 (1.8870)	84.20 (1.9251)	49.60 (1.6191)
Sabouraud dextrose agar	15.63 (1.3141)	40.77 (1.6102)	59.70 (1.7180)	63.02 (1.7993)	73.52 (1.8663)	86.45 (1.9366)	90.00 (1.9542)	61.30 (1.7427)
Mean	14.24 (1.1758)	22.95 (1.4249)	42.89 (1.6109)	49.16 (1.6835)	60.45 (1.7757)	71.82 (1.8501)	82.16 (1.9135)	

C.D. for comparison between treatment = 0.0127

C.D. for comparison between period = 0.0254

Figures in parenthesis are values after logarithmic transformation

GROWTH OF F. PALLIDOROSEUM ON DIFFERENT MYCOLOGICAL MEDIA

FIG 4

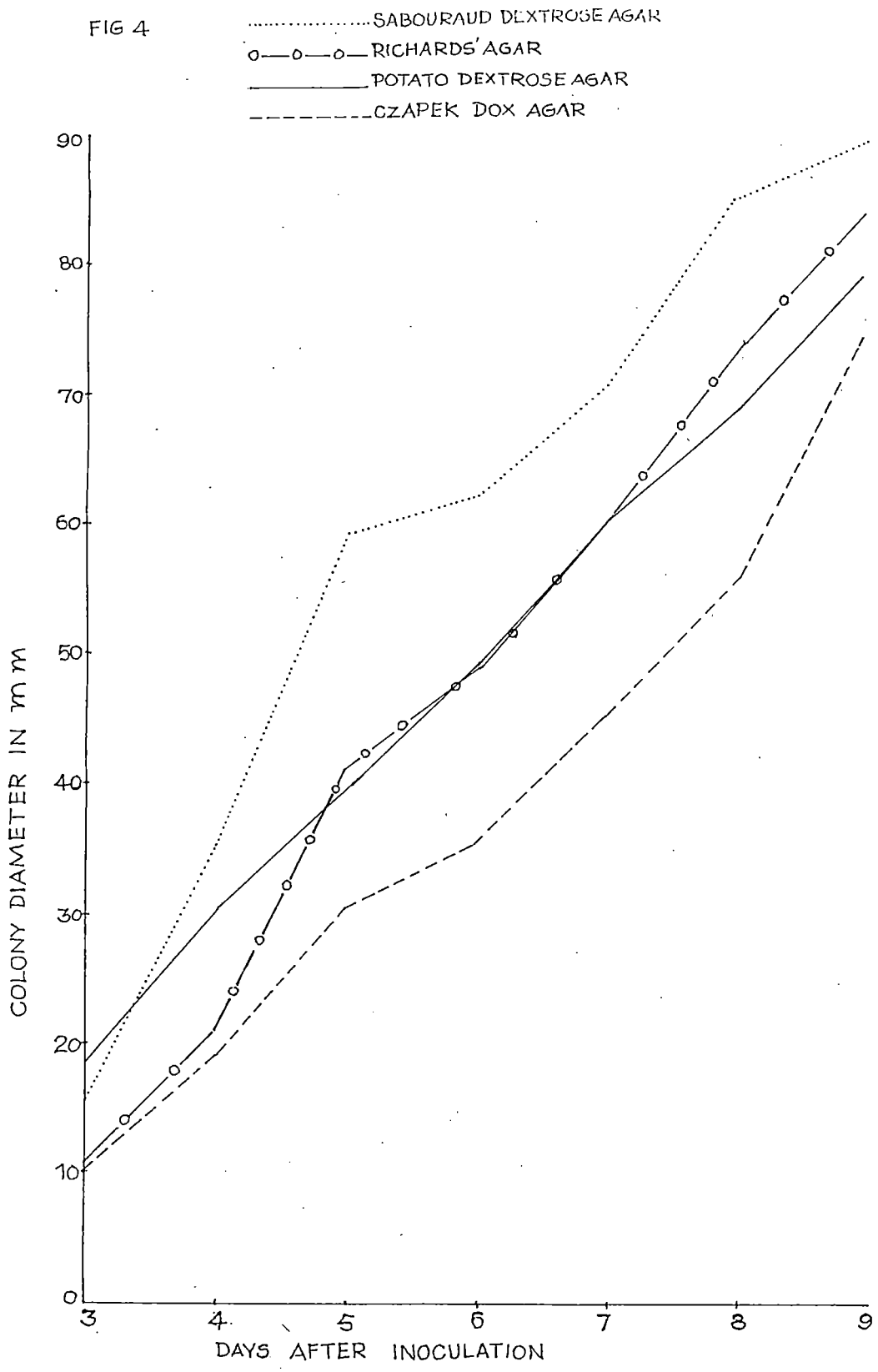


Table 7. Sporulation of F. pallidoroseum in different mycological media

Media used	Mean number of spores per ml obtained from the media at different intervals after inoculation (days)								
	2	3	4	5	6	7	8	9	Mean
Potato dextrose agar	1.53×10^{6} (6.185)	2.60×10^{6} (6.415)	3.34×10^{6} (6.525)	4.43×10^{6} (6.647)	5.03×10^{6} (6.702)	4.07×10^{6} (6.610)	3.20×10^{6} (6.505)	2.58×10^{6} (6.412)	3.18×10^{6} (6.503)
Richards' agar	1.57×10^{6} (6.197)	2.13×10^{6} (6.365)	3.18×10^{6} (6.502)	3.94×10^{6} (6.595)	4.24×10^{6} (6.627)	3.94×10^{6} (6.595)	2.64×10^{6} (6.422)	2.17×10^{6} (6.337)	2.85×10^{6} (6.455)
Czapek (Dox) agar	1.24×10^{6} (6.095)	1.81×10^{6} (6.257)	2.70×10^{6} (6.432)	3.69×10^{6} (6.567)	4.02×10^{6} (6.605)	3.27×10^{6} (6.515)	2.49×10^{6} (6.397)	1.57×10^{6} (6.197)	2.40×10^{6} (6.382)
Sabouraud dextrose agar	1.69×10^{6} (6.227)	2.99×10^{6} (6.475)	3.85×10^{6} (6.585)	4.86×10^{6} (6.687)	6.10×10^{6} (6.785)	6.56×10^{6} (6.817)	4.86×10^{6} (6.687)	3.91×10^{6} (6.197)	4.04×10^{6} (6. 82)
Mean	1.50×10^{6} (6.176)	2.39×10^{6} (6.378)	3.30×10^{6} (6.518)	4.19×10^{6} (6.621)	4.79×10^{6} (6.680)	4.31×10^{6} (6.634)	3.18×10^{6} (6.503)	2.41×10^{6} (6.383)	

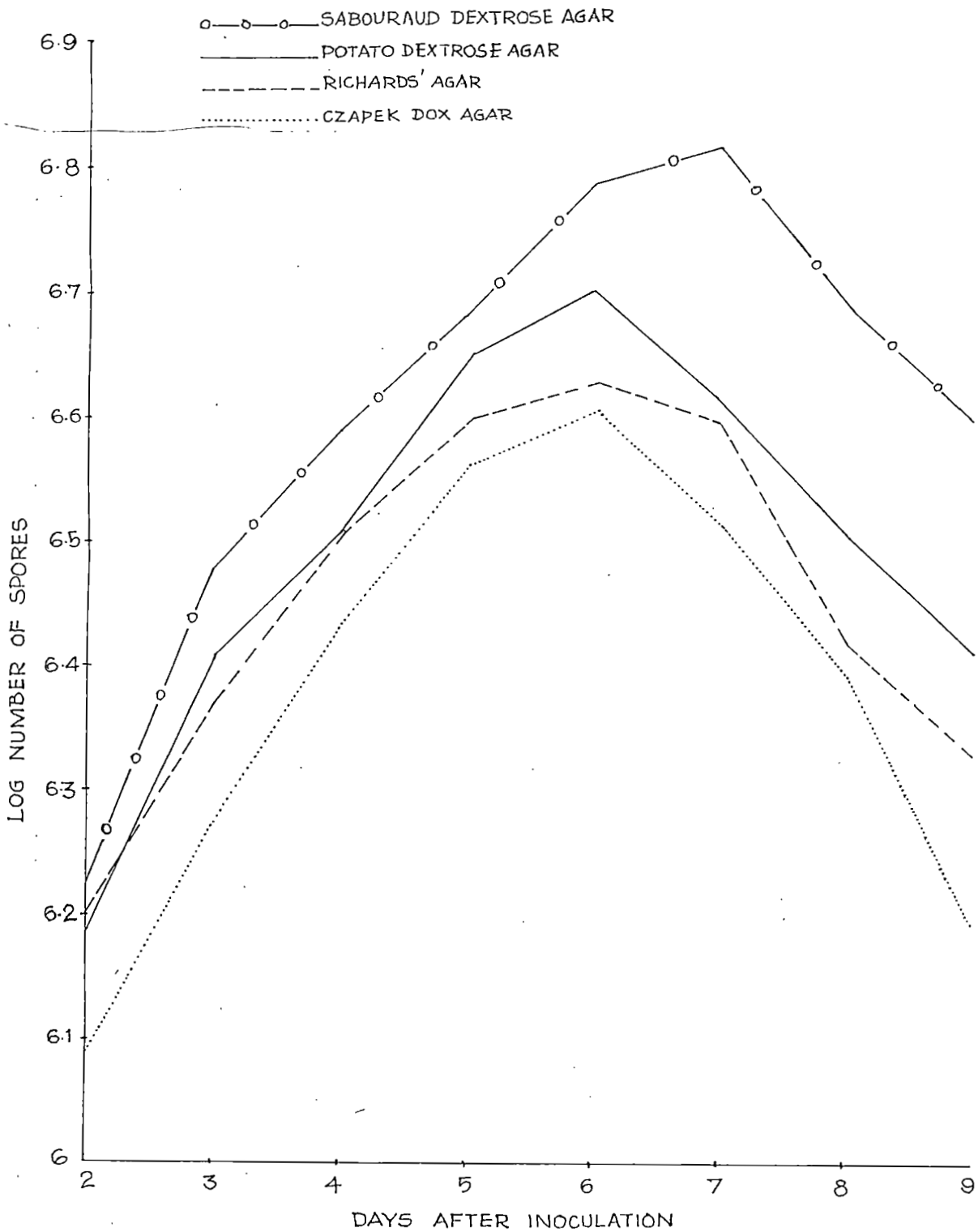
C.D. for comparison between treatment = 0.086

C.D. for comparison between period = 0.124

Figures in paranthesis are values after logarithmic transformation

FIG. 5

SPORULATION OF F. PALLIDOROSEUM IN DIFFERENT MYCOLOGICAL MEDIA ON DIFFERENT DAYS AFTER INOCULATION



on the sixth day with a mean spore count of 4.79×10^6 followed by seventh day and fifth day. A decline in the rate of sporulation is noticed from seventh day onwards.

Effect of different media on pathogenicity of the fungus F. pallidoroseum

Data on effect of composition of different media on pathogenicity of the fungus are presented in Table 8. Results showed considerable variation on the mortality of pea aphid inoculated with the spores of the fungus harvested from different culture media. Hundred per cent mortality of pea aphid on fourth day of inoculation was observed in the case of fungus cultured on Sabouraud dextrose agar medium. The fungus cultured on potato dextrose agar recorded 98.14 per cent mortality on fourth day of inoculation followed by Czapek (Dox) agar with 92 per cent mortality. Fungus cultured on Richards' agar medium recorded only 69.83 per cent cumulative mortality on fourth day showing that it is less virulent than the fungus cultured on other three media. The fungus cultured on Sabouraud dextrose agar showed a high degree of pathogenicity by giving a mortality of 72.99 per cent on the second day of inoculation itself. However, there was no significant difference between pathogenicity of fungus cultured on

Table 8. Pathogenicity of spores of F. pallidoroseum grown on different mycological media on A. craccivora

Media used	Mean per cent mortality of A. craccivora observed at different intervals after treatment (days)			
	1	2	3	4
Sabouraud dextrose agar	45.73 (42.532)	72.99 (58.069)	95.57 (77.820)	100.00 (90.000)
Richards' agar	7.20 (15.561)	22.58 (28.546)	51.47 (45.824)	69.83 (56.661)
Czapek (Dox) agar	28.19 (32.059)	52.64 (46.493)	62.19 (52.032)	92.00 (73.550)
Potato dextrose agar	48.74 (44.264)	66.44 (54.574)	80.16 (63.535)	98.15 (82.146)
C.D.	14.084	10.750	16.335	16.565

Figures in parenthesis are transformed values (angular)

Sabouraud dextrose agar medi[illegible] and potato dextrose agar medi[illegible].

Effect of age of culture on pathogenicity

Results presented in Table 9, show the influence of age of culture on the pathogenicity of the fungus. It is evident from the result that spores harvested from six and seven day old cultures recorded 100 per cent cumulative mortality at 72 hours after inoculation. Eight day and nine day old cultures gave only 81.23 and 58.01 per cent cumulative mortality at 72 hours showing a decline in pathogenicity of the fungus due to age of culture. There is significant difference in mortality due to age of culture at 48 hours after inoculation. The highest cumulative mortality of 89.37 per cent was recorded in the case of six day old culture, but the difference in per cent mortality due to age of culture was not significant at 24 hours after inoculatio[illegible]

Selection of suitable medium for mass culture of the fungus

The preliminary screening studies indicated the suitability of rice grain, wheat grain, ragi grain, broken maize grain, jack seed, coconut oil cake and dried tapioca chips for mass culturing of the fungus. Hence the sporulation of the fungus in these materials was studied and the results are presented in Table 10. It is seen that the sporulation of the fungus was maximum in

Table 9. Pathogenicity of the spores of F. pallidoroseum grown on Sabouraud dextrose agar at different intervals after inoculation

Age of culture in days	Cumulative per cent mortality at intervals (in hours)		
	24 hours	48 hours	72 hours
3	37.03 (37.46)	67.15 (55.01)	94.53 (76.44)
4	38.49 (38.33)	72.68 (58.46)	83.55 (66.04)
5	39.97 (39.20)	73.70 (50.13)	99.68 (86.76)
6	48.70 (44.24)	89.37 (70.95)	100.00 (90.00)
7	33.22 (35.18)	87.11 (68.93)	100.00 (90.00)
8	36.06 (36.89)	67.58 (52.27)	81.23 (64.29)
9	26.07 (30.69)	50.13 (45.06)	58.01 (49.58)
C.D.	9.34	14.58	10.76

(Figures in parentheses are values after angular transformation)

Plate No. 5 Growth of *F. pallidoroseum* on some mass multiplication media.

1 Rice grain

2 Wheat grain

3 Ragi grain

4 Maize grain

5 Cowpea

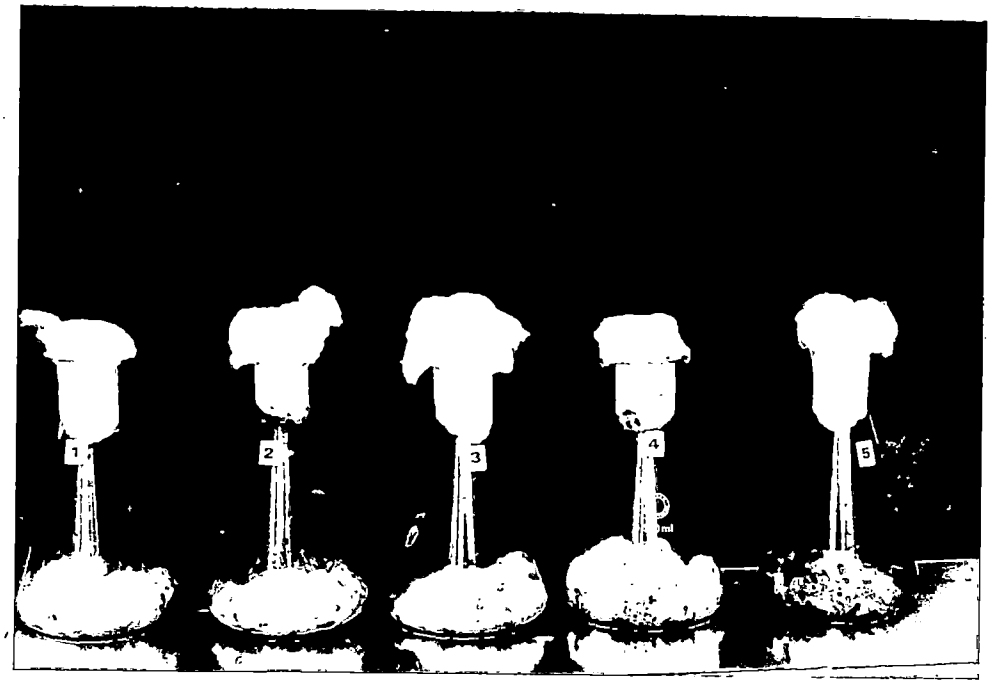
6 Greengram

7 Jack seed

8 Coconut oil cake

9 Tapioca chips

10 Paddy straw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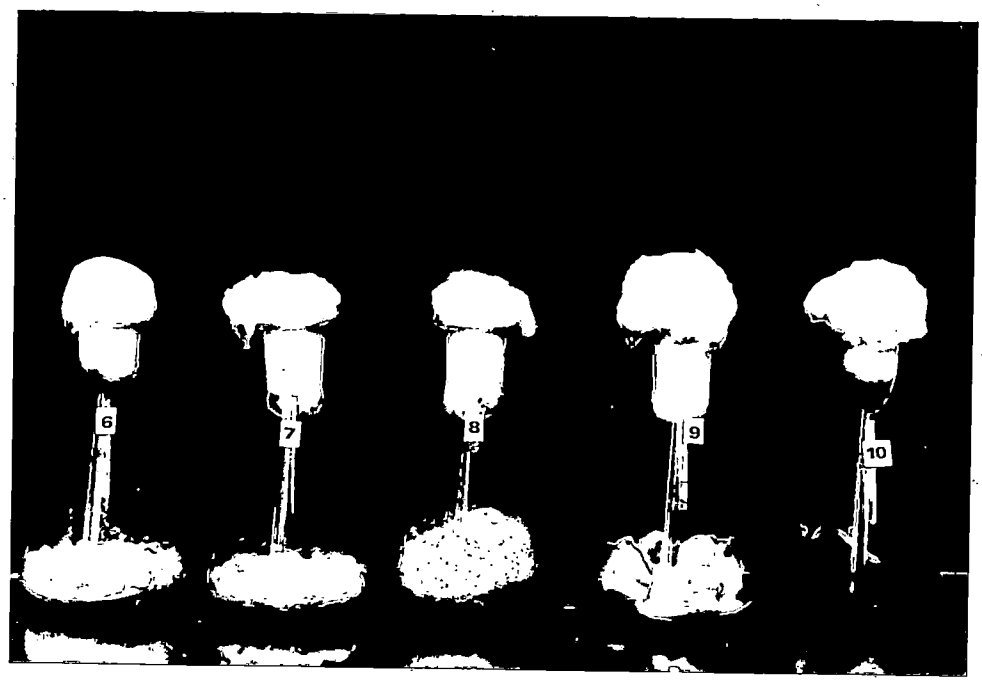
6
7
8
9
10

Table 16. Sporulation of F. pallidoroseum on different materials used for mass multiplication of the fungus

Media	Mean number of spores/ml on 9th day
Rice grain	1.41×10^6 (6.15)
Wheat grain	3.55×10^6 (6.55)
Ragi grain	1.41×10^6 (6.55)
Maize grain	4.90×10^6 (6.69)
Jack seed	3.02×10^6 (6.48)
Coconut oil cake	2.10×10^6 (6.32)
Tapioca chips	3.80×10^6 (6.58)

C.D. for comparison between different media 0.09

(Figures in parentheses are values after logarithmic transformation)

broken maize grain (4.90×10^6 spores per ml) followed by tapioca chips (3.80×10^6 spores per ml). The sporulation in maize was significantly superior to all other mass multiplication media tested. The lowest sporulation was recorded in rice and ragi grain.

Pathogenicity of fungus F. pallidoroseum to certain crop plants

Inoculation of the fungus on rice, bhindi, brinjal, chillies and tomato by three methods did not produce disease symptom in any of the inoculated plants indicating the safety of the fungus to these cultivated crop plants.

Safety of the fungus F. pallidoroseum to the predator Menochilus sexmaculata

All the ten grubs treated with the fungus and those of the control pupated and adults emerged within a period of five to eight days indicating that the fungus was not pathogenic to M. sexmaculata

Bioassay of F. pallidoroseum on pea aphid A. craccivora

The mortality caused by graded doses of fungus to pea aphid and the results of probit analysis showed that Lc_{50} of F. pallidoroseum on

adult pea aphid was 3.408 x 10^6 spores per ml.

Control of pea aphid with F. pallidoroseum

The results of the field experiment presented in Table 12 show that the fungus at the rate of 7 x 10^6 spores per ml and 3.5 x 10^6 spores per ml was as effective as the insecticide quinalphos 0.05 per cent for the control of pea aphid. These treatments were significantly superior to that of the lowest doses of the fungus and untreated check.

It can also be seen that one week after treatment, the maximum population of predator was observed in untreated plots followed by the lowest dose of the fungus. The lowest mean population of predator was observed in the insecticidal treatment. There was statistically significant decrease in the predator population in the insecticidal treatment, when compared to the different doses of the fungus and control.

Table 11. Effect of F. pallidoroseum on pea aphid and its predators in comparison with insecticide application

Treatments	Dose	Mean number of aphids		Mean number of predators	
		Before treatment	After treatment	Before treatment	After treatment
Spores of F. pallidoroseum	1.75×10^6/ml	10.458	5.022	1.606	1.361
"	3.50×10^6/ml	9.049	2.474	1.403	1.139
"	7.00×10^6/ml	8.527	1.434	1.640	1.033
Quinalphos	0.05 per cent	12.662	0.491	1.847	0.977
Control	-	8.168	14.080	1.672	1.714

C.D. for comparison between treatments 1. aphids = 1.398
2. predators = 0.202

DISCUSSION

DISCUSSION

Peaaphid Aphis craccivora Koch., a pest of regular occurrence in pulse crops, is found associated with the crop in its vegetative and reproductive phase causing heavy crop loss. A number of coccinellids and syrphids have been reported predating on the pest. The amount of control exerted by them on the pest population is not adequate at peak population level of the pest. The use of insecticides for the control of this persistant pest in a short duration crop like pulses is beset with the danger of pesticide residues and attendant toxic hazards. The phenomenon of resurgence of target species following insecticidal control has become a serious problem often associated with chemical control. An ecologically sound approach with minimum use of insecticides is necessary in this context to combat this pest.

A sound knowledge on the various biotic and abiotic factors and their influence on the population fluctuation of peaaphid in the field is a prerequisite to develop a pest management strategy with minimum disturbance to ecological balance. With this objective an attempt has been made in the present investigation to study the influence of various biotic and abiotic factors on the population fluctuation of peaaphid. A survey was also

conducted as a part of this investigation to identify an efficient microbial agent for the control of this pest. The fungus Fusarium pallidoroseum (Cooke) Sacc was found to be an efficient fungal pathogen of peaaphid and detailed studies leading to its utilization as a microbial agent against the pest was also taken up.

The first attempt was to study the population trend of peaaphid in the crop planted in different months. The influence of time of planting and stage of the crop on population fluctuation of peaaphid was studied for a period of one year. The maximum population of peaaphid was observed in the crop planted during November, October and December (1984). Population remained high in the plantings done from July to January (1985). A decline in the population was observed from February onwards with the lowest being in the planting done during March (1985). In a similar study Mathew et al. (1971) observed high population of peaaphid from September to April and a low population from May to August. Radhakrishnan (1969) recorded peak population of banana aphid Pentalonia nigronervosa from November to January. In Kerala, cowpea is raised mostly as a summer crop in rice fallows and low incidence of the pest during this period indicates the suitability of the season in raising the crop with minimum insecticide application.

Stage of the crop was found to have profound influence on the intensity of pest attack. A gradual increase in the aphid population was observed from the fourth week of planting reaching the peak in the eighth week. The maximum population of peaaphid coincide with the active reproductive phase of the crop. High susceptibility of cowpea to aphid infestation during its peak flowering period is indicated in these results. It may be possible that biochemical changes taking place within the plant at this stage is conducive to the rapid multiplication of the pest. This aspect needs further studies. The present study is in agreement with the report of Saharia (1981) that peak population density of A. craccivora coincided with pod formation in cowpea.

Population dynamics of any organism is influenced by biotic and abiotic factors of the environment. Each organism requires certain optimum climatic conditions for its growth and development. Similarly, the natural enemies also exert an equal regulatory influence, and flare up in population often coincideswith the failure of these agents to play their normal role. Some studies have been made in Kerala on the predatory potential of coccinellid and syrphid predators of A. craccivora. (Jacob, 1963; Sarala Devi, 1967; Mathew et al., 1971). But the factors

of the environment governing the population fluctuation of peaaphids under field condition in Kerala are however not fully understood.

Present studies reveal a significant positive correlation between population of peaaphids and relative humidity. The other weather parameters have not shown any significant influence on pest population changes. Multiple regression coefficient of aphid population with relative humidity was highly significant. Real (1956) observed that high relative humidity around 85 to 90 per cent in conjunction with high temperature of 23.9 to 29.4° C was congenial to the growth and reproduction of peaaphid. A similar temperature humidity relationship has been found with green peach aphid, Myzus persicae (Reed, 1964). Present results are in agreement with these findings. A temperature ranging between 22° C and 30° C and a relative humidity above 85 per cent prevailed during the peak population of the pest in the present study. Negative correlation between pest population and maximum temperature is evident from the lowest pest population observed in the crop planted during March, 1985. The negative correlation between rainfall and aphid population though not significant indicates the harmful effect of heavy rain on the population build up of the pest. The high degree of association between relative humidity and aphid population show that under the climatic conditions prevailing in Kerala,

humidity in general play an important role in conditioning the infestation of aphid on cowpea than any other factor.

In addition to the influence of weather factors on the population of peaaphid, the results revealed that predators exert a definite influence on the population of the prey. The highly significant positive correlation between predator population and aphid population shows that they are interdependant. The peaaphid and its predators show a similar trend in population fluctuation throughout the period of observation. The peak aphid population coincided with a peak inpredator population and vice versa. The density dependent nature of the predator was evident from the results. Mathew et al. (1971) observed similar trend in the population of peaaphid and its predators. The present study is in agreement with the contributions made by previous workers on predator-host relationship (Alle et al.,1949); Thompson, 1956 and David, 1963) have observed that abundance of a predator is linked with the abundance of its prey.

Correlation studies between population of aphid at different stages of the crop and environmental factors also showed a positive correlation between relative humidity and aphid population in all the stages of the crop observed. Similarly, the results revealed a

significant positive predator-prey relationship in all except the fourth week. None of the other factors was found to have any significant influence on aphid population in the various stages of the crop. Relative humidity and predators were found to be the deciding factors in determining the population fluctuation of aphids in the correlation worked out for the entire crop. The same relationship was observed in the influence of relative humidity and predators when the population of the pest on various growth stages of the crop was correlated with these factors. These results confirm the decisive role of these two factors in the population fluctuation of peaaphid. The application of insecticide at this stage to control the pest is not feasible due to residue problem in the harvested produce. Moreover insecticide induced resurgence of Aphis gossypii in cotton and bhindi has been reported by the application of Methyl parathion, carbaryl and phorate after an initial reduction in population. It was observed that nutritional superiority of the treated plants having lower carbohydrate content resulting in narrow C:N ratio and greater quantities of amino acids were the prime factors responsible for the preferential colonisation of aphids in them (Sithanantham et al 1973; Jayaraj and Reghupathy, 1987).

The survey conducted on the aphid population of pulse

crop in the Instructional farm, College of Agriculture, Vellayani and adjoining farmers fields during 1984 revealed the occurrence of F. pallidoroseum as a pathogenic fungus on A. craccivora. This is the first report of F. pallidoroseum as a pathogen of A. craccivora. Fussarium species are generally saprophytic or plant parasitic. But, a few species have been recorded as parasitic on insects especially coccids, aleyrodids, aphids, locusts and larvae of lepidoptera (Teodoro, 1937; Steinhaus, 1949; Steinhaus and Marsh, 1962; Viswanathan, 1972; Atwal et al., 1973; Nagalingam, 1983 and Raghavendra et al., 1987). Eventhough three fungal isolates were found associated with the aphids, only F. pallidoroseum was found pathogenic to peaaphids. The present survey was done in a limited area in the course of one year. Existence of other species of fungi pathogenic to aphid cannot be ruled out. A detailed survey covering different seasons a wider area may reveal other species of fungi pathogenic to aphids having the potential to effectively control aphids in field.

Observations made on morphological characters of F. pallidoroseum showed that the fungus produced one to seven septate conidia both over the host and artificial media. Booth and Sutton (1984) reported that the fungus produced primary conidia which are zero to five septate

and shorter and secondary conidia which are zero to seven septate. They have also reported that the fungus produced chlamydospores which are mostly intercalary with smooth or roughened walls. But chlamydospores could not be observed either in host insect or in artificial media in the present study.

Studies on the effect of composition of different media on growth of F. pallidoroseum showed that Sabouraud dextrose agar medium produced maximum growth within the shortest period than other media tried. The fungus grown on the other three media also showed satisfactory growth but the rate of growth was lesser than that of Sabouraud dextrose agar media. It indicates that the fungus is nonfastidious and it may grow on all conventional mycological medium. The rate of growth of the fungus was faster from 3rd to 7th day but from 8th day onwards it declined. Kuruvilla (1978) reported that F. oxysporum preferred Oatmeal agar than Richards' agar, Czapek (Dox) agar and Potato dextrose agar for its growth.

Sporulation of the fungus was maximum in Sabouraud dextrose agar medium followed by Potato dextrose agar. Sabouraud dextrose agar containing peptone was found to be more suitable for growth and sporulation.

Studies on virulence of the pathogen grown in different

media showed that there was significant variation in the lethal period of infection which indicates a variation in virulence. The fungus grown on Sabouraud dextrose agar stood first with maximum mortality of A. craccivora followed by Potato dextrose agar. When compared to the former two media spores harvested from Czapek (Dox) agar and Richards' agar recorded less mortality of aphids on the fourth day of inoculation indicating less virulence. Probably the speed of germination of conidia on insect may have a role in determining the pathogenicity of the fungal spores harvested from different media. It is generally believed that the way a fungus has been artificially cultured influences its virulence. (Madelin, (1963). Voukassovitch (1925) reported that spores of Spicaria farinosa from a peptone medium killed silk worm, whereas those from Potato dextrose agar did not. Schaerffenberg (1957) reported that to conserve the virulence of the pathogenic fungi particularly Beauveria bassiana it was essential to culture them in proteinacious media, a proceedure adopted also by Wallengren and Johanson (1929) with Metarrhizium anisopliae. Kuruvilla (1978) reported that for the artificial culture of F. oxysporum Oatmeal agar was the best. The present study showed that spores of F. pallidoroseum harvested from Sabouraud dextrose agar mediam

was significantly superior in virulence than from the other media indicating that constituents of the medium have significant influence on virulence of spores produced.

Studies on mortality of pea aphid caused by spores harvested from different day old cultures of the fungus on Sabouraud dextrose agar revealed high degree of virulence of six days and seven days old cultures causing 100 per cent cumulative mortality in 72 hours after inoculation. Maximum sporulation of the fungus was also recorded on six days old culture. These observations indicate that six to seven days is the optimum age of F. pallidoroseum in Sabouraud dextrose agar for maximum pathogenicity.

A suitable medium for culturing an entomopathogenic fungus is one which can produce maximum growth of the fungus and spores with high degree of virulence within the shortest period. In the present studies Sabouraud dextrose agar medium was found to produce maximum growth and sporulation of the fungus within the shortest period. But maximum sporulation in a medium need not be a proof of its pathogenicity. The fungus cultured on Sabouraud dextrose agar has proved its superiority in pathogenicity also giving 100 per cent mortality of the host insect on the fourth day of inoculation. It is quite clear from these results that Sabouraud dextrose agar medium is the most

suitable for culturing F. pallidoroseum. Since an entomopathogenic fungus has to invade the insect cuticle to cause infection it may be of interest to study the influence of a medium containing chitin as a source of carbon and nitrogen on the growth sporulation and pathogenicity of the fungus as observed in the case of Verticillium lecanii (Hall,1981).

A good candidate pathogen for successful mocrobial control programme should be amenable for easy mass production on cheaper locally available materials so that it can be multiplied for field application at reasonable cost. Cheap materials of plant origin have been screened by various workers for the mass production of several insect pathogenic fungi (Forbes, 1895; Fawcett, 1908; Celino, 1930; Hall and Dunn, 1958; Martignoni, 1964; Villacorta, 1976; Easwaramoorthy et al., 1976 and Nagalingam, 1983). Mass production of F. pallidoroseum was attempted in the present studies using rice, maize, wheat, ragi, jack seed, coconut oil cake and tapioca chips after a preliminary screening of ten materials. Maize grain recorded maximum sporulation followed by tapioca chips. Though all the cheaper materials tested produced spores, broken maize grain appeared to be most suitable as it produced maximum sporulation. Tapioca chips and jack seed also gave good sporulation eventhough slightly

inferior to maize. But these two materials are cheaper and easily available. Further studies with a wide range of materials on growth, sporulation and virulence of the fungus may lead to identification of still cheaper materials for its mass production. Kuruvilla (1978) recorded that for mass production of spores of F. oxysporum green gram and wheat appeared to be the most suitable materials. Hussey and Tinsley (1981) reported that in China Beauveria bassiana is mass cultured on materials like wheat bran, rice powder, compost humus and ground corn stalks. These materials were steamed but not autoclaved before use. Nagalingam (1983) found that for mass production of Fusarium semitectum broken maize grain + blackgram husk or greengram husk 4:1 (w/w) was highly suitable. Raghavendra et al. (1987) used moist sterile sorghum grains for mass production of Fusarium subglutinans in Tamilnadu.

Nonpathogenicity to common predators and parasites encountered in the field is an ideal attribute for any candidate entomopathogen. Menochilus sexmaculata has been reported as the most efficient among the coccinellid predators preying upon pea aphid (Saharia, 1981). The present finding that F. pallidoroseum is nonpathogenic to this predator establishes its suitability as a biocontrol agent. Safety test done by Nagalingam (1983) using

F. semitectum has showed that it is safe to all instars of mulberry silk worm and adult honey bee, hymenopterous parasites and coccinellid predators of Myzus persicae.

Observations on the pathogenicity of F. pallidoroseum to crop plants like rice, bhindi, brinjal, chillies and tomato showed that the fungus is not pathogenic to these crop plants, though they have been recorded as susceptible to certain species of Fusarium causing damping off and wilt disease. F. pallidoroseum thus appears to be a specific entomopathogenic fungus safe to the crop plants tested. Nonpathogenicity to crop plants is an essential character of an entomopathogenic fungus if it is to be recommended for field use. However, further screening of the commonly cultivated crop plants in Kerala should be taken up before large scale field use of the fungus is recommended. Gopinath et al. (1982) reported that Fusarium equiseti and Fusarium moniliformae two entomopathogenic fungi as safe to cotton, tomato, bittergourd, snakegourd and brinjal. Nagalingam (1983) has reported that F. semitectum was safe to crop plants like chillies, cabbage, brinjal and tobacco.

To test the biological efficiency of any entomopathogen, a bioassay on the host insect gives the most reliable results. Bioassay of F. pallidoroseum has shown that Lc50 of the fungus against adult pea aphid was 3.408×10^{6} spores per ml.

The results of the field experiment revealed that under field conditions also the fungus can cause mortality in aphid population,and can effectively check its population build up. The fungus applied at the rate of 7×10^6 and 3.5×10^6 conidia per ml of spray solution was found to be equally effective in controlling pea aphids. These fungal treatments were comparable to the insecticide viz. quinalphos 0.05 per cent in bringing down the population of pea aphid in the course of a week. The insecticidal treated plants recorded lower number of predators than plots treated with the fungus. The safety of the fungus to coccinellid predator M. sexmaculata was already established in the safety test conducted under laboratory conditions. The treatment 1.625×10^6 spores per ml was inferior to the other doses indicating that concentration of spores in the fungus inoculum applied has significant role in initiating epizootic and bringing effective check on pest population. The high degree of virulence of the fungus is evident from its effectiveness in controlling pea aphid under field conditions even at a dose of 3.5×10^6 spores per ml. The field efficacy of entomogenous fungi have been reported by many workers. Kuruvila and Jacob (1979) reported that F. oxysporum applied at the rate of 6.25×10^6 spores per ml on

on brown plant hopper, Nilaparvata lugens (Stal.) caused 100 per cent mortality. Easwaramoorthy et al. (1978) reported that V. lecanii caused 95.6 per cent mortality of coffee green bug Coccus viridis at 16 x 10^6 spores per ml along with 0.05 per cent Tween or Teepol 0.0 per cent. The climatic factors especially humidity has an important role in producing fungal epizootics. Ecological studies aimed at determining the adaptability of the pathogen during different seasons are necessary to ascertain its ability as a biocontrol agent.

Strategy for pest management is the regulation of pest population below the levels causing economic loss with least disruption to the ecological balance. Control of a persistant pest like pea aphid A. craccivora in a crop like cowpea which is raised as a vegetable in Kerala with insecticides is not ecologically sound in the context of insecticide induced resurgence of aphids reported in cotton and bhindi (Seetharaman et al. 1973; Reghupathy and Jayaraj, 1973). Moreover it is not economically viable in a low value crop like cowpea. In the present instance the effectiveness of the fungus Fusarium pallidoroseum (Cooke) Sacc. against pea aphid has been demonstrated in laboratory and field tests. The fungus was found amenable

to mass culture on cheaper locally available materials like maize grain, tapioca chips and jack seed. Safety of the pathogen to the coccinellid predator M. sexmaculata and few crop plants was also established. All these attributes make F. pallidoroseum an ideal biocontrol agent of pea aphid.

SUMMARY

SUMMARY

Investigations were carried out on the population fluctuation of pea aphid Aphis craccivora Koch. on cowpea in relation to month of planting and stage of the crop. Fluctuation of pea aphid population in relation to weather factors and predators were also studied. A survey was conducted with a view to identifying pathogens of pea aphid for utilization as a bio-control agent.

Studies on the influence of time of planting on aphid population has shown that the maximum population of pea aphid occured in November planted crop followed by the crop planted in December and October. The lowest population was noticed in the crop planted during March. The most susceptible stage of the crop to pea aphid was found to be the active reproductive phase.

Correlation studies have shown that relative humidity has a significant role in the population build up of pea aphid. Other weather parameters did not show any significant influence on pea aphid population. The general population trend of the predators showed a similar pattern to that of the host showing its density dependent nature. There was significant positive correlation between aphid and its predators.

In the survey conducted, Fusarium pallidoroseum (Cooke)

Sacc. was identified as a pathogen of pea aphid. Detailed investigations were carried out on this fungus. It was found that the fungus is highly pathogenic to pea aphid under laboratory conditions.

Among the different artificial media used, Sabouraud agar medi. produced maximum growth and sporulation of the fungus. Maximum sporulation of the fungus was observed in six day old cultures. Pathogenicity test showed that the spores of the fungus harvested from 7 day old culture in Sabouraud medi. caused 100 per cent mortality of adult pea aphid. For mass production of F. pallidoroseum ten materials were screened of which maize grain followed by tapioca chips and paddy straw were found suitable. The fungus was found non pathogenic to the predator M. sexmaculata. It was not pathogenic to crop plants viz. rice, bhindi, brinjal, chillies and tomato. LC_{50} of the fungus to adult pea aphid was found to be 3.408×10^6 spores per ml.

Studies on the efficacy of the pathogen in controlling the pest under field conditions showed that application of a spore suspension at the rate of 3.5×10^6 spores per ml and 7×10^6 spores per ml was as effective as the insecticide, quinalphos 0.05 per cent in controlling the pest. The predator population was found reduced in the insecticidal

treatment, when compared to fungus treated plots. The results revealed that F. pallidoroseum has the potential for development as a biocontrol agent against pea aphid.

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ABSTRACT OF A THESIS

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1989

ABSTRACT

Studies were made to collect information on the population fluctuation of pea aphid Aphis craccivora Koch. a regular pest of cowpea in relation to time of planting and stage of the crop. The population fluctuation of pea aphid in relation to the prevailing weather factors and the predators were also investigated to collect information on host predator interactions and interrelations. A survey on the occurrence of fungal pathogens associated with pea aphid was conducted in the pulse crops raised at the Instructional Farm, College of Agriculture, Vellayani and adjacent farmers fields. The suspected fungi were isolated and their pathogenicity tested in the laboratory. Pathogenicity could be proved only in the case of Fusarium pallidoroseum (Cooke) Sacc. Detailed studies were made on its growth, sporulation and pathogenicity using different artificial culture media.

It was observed that the cowpea crop planted during November recorded maximum population of pea aphid followed by crop planted during October and December. Lowest population of pea aphid was noticed in the crop planted during March. The active reproductive stage of the crop recorded maximum population of pea aphids. Correlation studies with weather factors and predator population revealed that

relative humidity and predator population was positively correlated with the population of pea aphid. Regression analysis of the data obtained indicated that 84 per cent of variation of population could be accounted by the variables under study. Partial regression coefficient of the aphid population and relative humidity was found to be positive and significant. Partial regression coefficient between pea aphid population and predator population was also positive and highly significant.

Studies on the pathogenicity of F. pallidoroseum showed that pea aphid infected with the fungus turned pale and assumed a brownish black discolouration. Death occurred in 48 to 72 hours after infection and white mycelial growth appeared on the cadavers 24 to 48 hours after death. Growth, sporulation and virulence of the fungus was found to be superior in Sabouraud medium followed by potato dextrose agar. Sporulation was maximum in 6 day old culture and virulence was highest in 6 day and 7 day old cultures. For mass production of the fungus broken maize grain appeared to be the most suitable media followed by tapioca chips and jack seed as they produced maximum number of spores.

Studies on the safety aspects of the pathogen showed that the fungus was not pathogenic to the crop plants tested

viz. rice, bhindi, chillies and tomato and also to the predator Menochilus sexmaculata. Bioassay showed that LC_{50} of the fungus to pea aphid was 3.408×10^6 spores per ml.

Field experiment to test the efficacy of the fungus in controlling aphid population revealed that the fungus at the rate of 7 to 10^6 spores per ml and 3.5×10^6 spores per ml was as effective as the insecticide quinalphos 0.05 per cent. The fungal treatment did not show any harmful effects on predator population in the field.

APPENDICES

Appendix I i

Population of pea aphid observed on cowpea planted in the month of October 1984

Stage of crop	Number of aphids per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0.0	4.3	0.0	4.3	4.3	0.0	4.3	4.3	0.0	71.9
5th week	71.9	192.6	4.3	192.6	192.6	192.6	71.9	192.6	192.6	192.6
6th week	192.6	192.6	192.6	192.6	192.6	192.6	71.9	192.6	71.9	192.6
7th week	192.6	458.7	71.9	192.6	192.6	458.7	192.6	192.6	192.6	458.7
8th week	71.9	458.7	458.7	192.6	458.7	458.7	458.7	71.9	458.7	458.7
9th week	71.9	71.9	458.7	71.9	458.7	71.9	192.6	458.7	458.7	458.7
10th week	458.7	71.9	192.6	71.9	192.6	71.9	71.9	458.7	458.7	192.6
11th week	458.7	192.6	192.6	71.9	192.6	192.6	71.9	192.6	192.6	71.9

Appendix I ii

Population of pea aphid observed on cowpea planted in the month of November 1984

Stage of crop	Number of aphids per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0.0	71.9	71.9	192.6	71.9	71.9	0.0	192.6	0.0	192.6
5th week	192.6	192.6	192.6	192.6	458.7	71.9	192.6	71.9	71.9	458.7
6th week	192.6	192.6	71.9	192.6	458.7	192.6	192.6	458.7	192.6	192.6
7th week	192.6	458.7	458.7	192.6	192.6	458.7	458.7	458.7	192.6	192.6
8th week	192.6	458.7	458.7	458.7	458.7	458.7	458.7	458.7	458.7	458.7
9th week	458.7	458.7	458.7	192.6	458.7	458.7	458.7	458.7	458.7	458.7
10th week	458.7	458.7	192.6	192.6	192.6	192.6	458.7	458.7	192.6	192.6
11th week	192.6	192.6	192.6	71.9	192.6	71.9	192.6	192.6	192.6	192.6

Appendix I iii

Population of pea aphid observed on cowpea planted in the month of December 1984

Stage of crop	Number of aphids per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	4.3	4.3	71.9	71.9	4.3	71.9	71.9	71.9	4.3	192.6
5th week	71.9	192.6	192.6	192.6	192.6	192.6	192.6	458.7	192.6	192.6
6th week	71.9	71.9	458.7	192.6	192.6	458.7	192.6	458.7	192.6	192.6
7th week	192.6	192.6	458.7	192.6	192.6	458.7	192.6	192.6	192.6	192.6
8th week	192.6	192.6	458.7	458.7	192.6	71.9	192.6	192.6	192.6	192.6
9th week	192.6	192.6	458.7	458.7	71.9	71.9	192.6	71.9	71.9	192.6
10th week	192.6	192.6	192.6	192.6	71.9	71.9	71.9	71.9	71.9	192.6
11th week	71.9	192.6	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9

Appendix I iv

Population of pea aphid observed on cowpea planted in the month of January 1985

Stage of crop	Number of aphids per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	4.3	4.3	71.9	71.9	4.3	71.9	71.9	71.9	71.9	192.6
5th week	71.9	192.6	71.9	192.6	192.6	458.7	192.6	71.9	192.6	192.6
6th week	71.9	71.9	71.9	192.6	192.6	458.7	458.7	192.6	192.6	192.6
7th week	192.6	192.6	192.6	192.6	192.6	458.7	192.6	192.6	192.6	192.6
8th week	192.6	192.6	458.7	458.7	71.9	71.9	71.9	192.6	192.6	192.6
9th week	71.9	192.6	192.6	458.7	71.9	71.9	71.9	71.9	71.9	192.6
10th week	4.3	71.9	192.6	192.6	4.3	71.9	71.9	192.6	71.9	71.9
11th week	4.3	4.3	71.9	4.3	4.3	71.9	71.9	4.3	4.3	4.3

Appendix I v

opulation of pea aphid observed on cowpea planted in the month of February 1985

tage of crop	Number of aphids per sample									
	1	2	3	4	5	6	7	8	9	10
th week	4.3	4.3	71.9	4.3	4.3	71.9	71.9	71.9	192.6	4.3
th week	71.9	192.6	192.6	192.6	71.9	192.6	192.6	192.6	192.6	71.9
th week	71.9	192.6	71.9	192.6	71.9	192.6	192.6	192.6	192.6	192.6
th week	192.6	71.9	192.6	71.9	192.6	192.6	71.9	192.6	71.9	71.9
th week	4.3	71.9	71.9	71.9	4.3	4.3	0.0	4.3	4.3	71.9
th week	4.3	0.00	000	4.3	0.0	0.0	4.3	4.3	0.0	71.9
th week	4.3	0.0	0.0	4.3	0.0	0.0	4.3	0.0	0.0	71.9
th week	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	4.3

Appendix I vi

Population of pea aphid observed on cowpea planted in the month of March 1985

Stage of crop	Number of aphids per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5th week	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6th week	0.0	4.3	0.0	0.0	4.3	0.0	0.0	0.0	0.0	4.3
7th week	0.0	4.3	0.0	0.0	4.3	0.0	0.0	0.0	0.0	71.9
8th week	0.0	71.9	0.0	4.3	4.3	4.3	71.9	0.0	0.0	4.3
9th week	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0
10th week	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0
11th week	0.0	0.0	0.0	71.9	0.0	4.3	0.0	0.0	0.0	0.0

Appendix I vii

opulation of pea aphid observed on cowpea planted in the month of April 1985

tage of crop	Number of aphids per sample									
	1	2	3	4	5	6	7	8	9	10
th week	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0
th week	0.0	0.0	0.0	0.0	71.9	4.3	0.0	71.9	4.3	0.0
th week	0.0	4.3	71.9	4.3	71.9	4.3	4.3	71.9	71.9	4.3
th week	71.9	71.9	71.9	71.9	71.9	71.9	4.3	192.6	71.9	71.9
th week	71.9	192.6	192.6	71.9	71.9	192.6	192.6	458.7	71.9	192.6
th week	71.9	192.6	192.6	71.9	71.9	458.7	458.7	192.6	192.6	192.6
th week	192.6	192.6	458.7	192.6	71.9	192.6	458.7	458.7	192.6	192.6
th week	71.9	71.9	192.6	192.6	71.9	192.6	192.6	71.9	192.6	192.6

Appendix I viii

Population of pea aphid observed on cowpea planted in the month of May 1985

Stage of crop	Number of aphids per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0.0	0.0	4.3	0.0	0.0	0.0	4.3	4.3	71.9	0.0
5th week	4.3	71.9	71.9	4.3	0.0	71.9	71.9	71.9	71.9	71.9
6th week	4.3	71.9	71.9	71.9	4.3	192.6	71.9	71.9	71.9	71.9
7th week	4.3	71.9	71.9	71.9	71.9	71.9	192.6	71.9	71.9	4.3
8th week	4.3	71.9	4.3	4.3	71.9	4.3	71.9	4.3	4.3	0.0
9th week	0.0	4.3	71.9	0.0	4.3	0.0	71.9	4.3	4.3	0.0
10th week	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11th week	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix I ix

Population of pea aphid observed on cowpea planted in the month of June 1985

Stage of crop	Number of aphids per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5th week	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6th week	0.0	0.0	0.0	4.3	71.9	4.3	0.0	0.0	0.0	0.0
7th week	4.3	0.0	4.3	4.3	71.9	192.6	71.9	4.3	71.9	4.3
8th week	192.6	4.3	458.7	192.6	192.6	192.6	71.9	192.6	192.6	4.3
9th week	192.6	458.7	458.7	192.6	458.7	458.7	71.9	458.7	192.6	192.6
10th week	192.6	458.7	458.7	192.6	458.7	192.6	192.6	192.6	192.6	192.6
11th week	71.9	71.9	192.6	71.9	458.7	71.9	71.9	192.6	71.9	71.9

Appendix I x

Population of pea aphid observed on cowpea planted in the month of July 1985

Stage of crop	Number of aphids per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0.0	4.3	71.9	4.3	0.0	4.3	71.9	0.0	4.3	0.0
5th week	4.3	192.6	71.9	71.9	71.9	4.3	192.6	71.9	71.9	71.9
6th week	192.6	192.6	71.9	71.9	192.6	192.6	458.7	458.7	192.6	192.6
7th week	192.6	192.6	192.6	71.9	192.6	458.7	458.7	192.6	192.6	192.6
8th week	192.6	192.6	192.6	71.9	71.9	192.6	0.0	192.6	458.7	192.6
9th week	192.6	192.6	192.6	71.9	458.7	192.6	0.0	192.6	192.6	458.7
0th week	71.9	71.9	458.7	192.6	458.7	192.6	0.0	458.7	192.6	71.9
1th week	4.3	4.3	71.9	71.9	192.6	4.3	0.0	192.6	71.9	4.3

Appendix I xi

Population of pea aphid observed on cowpea planted in the month of August 1985

Stage of crop	Number of aphids per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0.0	4.3	71.9	0.0	4.3	71.9	0.0	71.9	0.0	0.0
5th week	71.9	192.6	71.9	4.3	192.6	192.6	4.3	71.9	0.0	0.0
6th week	71.9	458.7	192.6	192.6	458.7	458.7	71.9	458.7	4.3	71.9
7th week	192.6	458.7	458.7	192.6	458.7	458.7	192.6	192.6	71.9	71.9
8th week	192.6	458.7	458.7	458.7	192.6	458.7	192.6	192.6	71.9	71.9
9th week	458.7	458.7	458.7	192.6	192.6	192.6	458.7	192.6	71.9	71.9
10th week	458.7	192.6	192.6	458.7	71.9	192.6	458.7	71.9	71.9	192.6
11th week	71.9	71.9	192.6	192.6	4.3	4.3	192.6	4.3	4.3	71.9

Appendix I xii

Population of pea aphid observed on cowpea planted in the month of September 1985

Stage of crop	Number of aphids per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0.0	0.0	4.3	0.0	0.0	4.3	4.3	0.0	4.3	0.0
5th week	0.0	71.9	192.6	71.9	0.0	71.9	71.9	4.3	192.6	0.0
6th week	71.9	71.9	192.6	192.6	0.0	192.6	192.6	192.6	192.6	4.3
7th week	71.9	192.6	192.6	192.6	4.3	458.7	458.7	192.6	71.9	71.9
8th week	71.9	192.6	192.6	192.6	71.9	192.6	458.7	458.7	71.9	71.9
9th week	71.9	192.6	192.6	192.6	192.6	458.7	458.7	458.7	192.6	192.6
0th week	71.9	71.9	192.6	192.6	458.7	458.7	192.6	458.7	192.6	192.6
1th week	4.3	71.9	458.7	192.6	458.7	458.7	192.6	458.7	192.6	71.9

Appendix II i

Population of predators of pea aphid observed on cowpea planted in the month of October 1984

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	0	0	0	0	0	0	0	0	2
5th week	0	1	0	3	1	2	0	1	1	2
6th week	1	2	0	2	3	3	2	1	0	2
7th week	1	2	0	1	2	2	3	2	2	2
8th week	0	2	1	0	4	2	3	0	3	3
9th week	0	0	1	0	3	0	2	3	2	3
10th week	7	2	1	0	1	0	0	2	2	2
11th week	4	3	0	0	0	0	0	3	3	2

Appendix II ii

Population of predators of pea aphid observed on cowpea planted in the month of November 1984

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	0	0	0	0	0	0	3	0	2
5th week	1	1	3	1	0	3	0	2	3	4
6th week	2	2	0	1	3	1	2	3	3	1
7th week	4	3	5	4	3	4	7	6	3	4
8th week	4	3	5	7	3	1	4	6	4	2
9th week	5	4	3	3	3	5	3	4	4	5
10th week	5	4	2	2	2	2	3	5	2	2
11th week	0	3	2	2	2	1	2	2	1	1

Appendix II iii

Population of predators of pea aphid observed on cowpea planted in the month of December 1984

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	0	0	0	0	0	0	0	0	0
5th week	0	1	2	1	0	3	0	1	1	1
6th week	2	2	5	3	1	3	2	4	2	2
7th week	2	1	4	3	3	7	3	2	2	1
8th week	2	2	4	4	3	4	0	3	3	1
9th week	1	3	5	4	1	1	1	3	4	1
10th week	1	3	3	1	1	0	0	3	2	1
11th week	0	3	1	0	0	0	0	0	0	0

Appendix II iv

Population of predators of pea aphid observed on cowpea planted in the month of January 1985

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	1	0	0	0	0	0	0	0	0
5th week	0	3	2	1	0	3	0	4	1	2
6th week	0	1	2	3	0	4	2	4	2	1
7th week	1	2	3	3	0	5	3	2	4	3
8th week	2	3	4	4	3	1	3	3	5	2
9th week	1	3	3	3	1	0	0	2	1	1
10th week	0	1	0	1	0	0	4	1	0	0
11th week	0	0	0	0	0	0	2	0	0	0

Appendix II v

Population of predators of pea aphid observed on cowpea planted in the month of February 1985

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	0	0	0	0	0	0	0	0	0
5th week	0	1	1	1	0	0	3	1	1	0
6th week	0	3	0	2	0	3	4	2	2	0
7th week	1	1	2	0	3	0	0	4	0	0
8th week	0	1	1	2	0	0	0	0	0	1
9th week	0	0	0	0	0	0	0	0	0	1
10th week	0	0	0	0	0	0	0	0	0	0
11th week	0	0	0	0	0	0	0	0	0	0

Appendix II vi

Population of predators of pea aphid observed on cowpea planted in the month of March 1985

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	0	0	0	0	0	0	0	0	0
5th week	0	0	0	0	0	0	0	0	0	0
6th week	0	0	0	0	0	0	0	0	0	0
7th week	0	0	0	0	0	0	0	0	0	0
8th week	0	0	0	0	0	0	0	0	0	0
9th week	0	0	0	0	0	0	0	0	0	0
0th week	0	0	0	0	0	0	0	0	0	0
1th week	00	0	0	0	0	0	0	0	0	0

Appendix II vii

Population of predators of pea aphid observed on cowpea planted in the month of April 1985

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	0	0	0	0	0	0	0	0	0
5th week	0	0	0	0	0	0	0	0	0	0
6th week	0	0	0	0	0	0	0	0	0	0
7th week	0	0	0	0	0	0	0	0	0	0
8th week	0	2	0	0	1	2	0	4	0	0
9th week	1	1	0	1	0	4	3	1	2	1
0th week	3	2	2	1	0	2	3	3	2	1
1th week	0	1	2	2	0	2	2	2	1	1

Appendix II viii

Population of predators of pea aphid observed on cowpea planted in the month of May 1985

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	0	0	0	0	0	0	0	0	0
5th week	0	0	0	0	0	0	0	0	0	0
6th week	0	0	0	0	0	0	0	0	0	0
7th week	0	0	0	0	0	0	0	0	0	0
8th week	0	0	0	0	0	0	0	0	0	0
9th week	0	0	0	0	0	0	0	0	0	0
10th week	0	0	0	0	0	0	0	0	0	0
11th week	0	0	0	0	0	0	0	0	0	0

Appendix II ix

Population of predators of pea aphid observed on cowpea planted in the month of June 1985

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	0	0	0	0	0	0	0	0	0
5th week	0	0	0	0	0	0	0	0	0	0
6th week	0	0	0	0	0	0	0	0	0	0
7th week	0	0	0	0	0	0	0	0	0	0
8th week	2	1	2	1	1	1	0	2	3	0
9th week	3	4	4	1	2	3	0	3	2	1
10th week	4	5	3	2	4	1	0	0	3	2
11th week	3	2	2	1	3	0	0	0	0	0

Appendix II x

Population of predators of pea aphid observed on cowpea planted in the month of July 1985

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	0	0	0	0	0	0	0	0	0
5th week	0	0	0	0	0	0	0	0	0	0
6th week	1	1	0	0	2	4	3	6	2	2
7th week	3	2	1	0	4	3	3	2	1	1
8th week m	3	2	0	0	3	1	0	3	1	2
9th week	3	2	1	0	2	1	0	2	1	2
0th week	1	0	2	1	3	1	0	2	1	1
1th week	0	0	2	1	3	0	0	3	1	0

Appendix II xi

aphid observed on cowpea planted in the month of August 1985

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	0	0	0	0	0	0	0	0	0
5th week	0	2	0	0	1	1	0	0	0	0
6th week	0	3	1	2	2	3	0	4	0	1
7th week	0	3	3	2	3	4	0	2	0	1
8th week	2	5	3	4	2	4	1	1	0	2
9th week	3	5	3	2	1	2	3	3	0	1
10th week	4	3	3	2	0	2	4	0	2	1
11th week	0	0	1	1	0	0	1	0	0	1

Appendix II xii

Population of predators of pea aphid observed on cowpea planted in the month of September 1985

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	0	0	0	0	0	0	0	0	0
5th week	0	0	0	0	0	0	0	0	0	0
6th week	0	0	2	3	0	1	2	3	4	0
7th week	0	2	2	2	0	5	5	2	2	0
8th week	0	3	2	2	0	3	4	5	0	1
9th week	0	4	2	5	1	4	3	4	1	2
10th week	0	3	1	2	3	5	3	3	3	2
11th week	0	1	3	3	3	4	2	4	1	2

Appendix II xi

Population of predators of pea aphid observed on cowpea planted in the month of August 1985

Stage of crop	Number of predators per sample									
	1	2	3	4	5	6	7	8	9	10
4th week	0	0	0	0	0	0	0	0	0	0
5th week	0	2	0	0	1	1	0	0	0	0
6th week	0	3	1	2	2	3	0	4	0	1
7th week	0	3	3	2	3	4	0	2	0	1
8th week	2	5	3	4	2	4	1	1	0	2
9th week	3	5	3	2	1	2	3	3	0	1
0th week	4	3	3	2	0	2	4	0	2	1
1th week	0	0	1	1	0	0	1	0	0	1