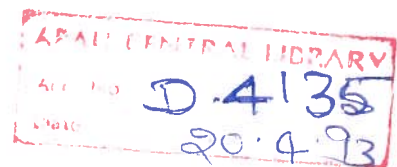


ECOLOGY AND CONTROL OF KEY PESTS OF CABBAGE



BY

V. D. V. N. H. KUMAR

B.Sc. (Ag.)

THESIS SUBMITTED TO THE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE



ANGRAU
Central Library
Hyderabad



004135

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE, RAJENDRANAGAR
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
RAJENDRANAGAR, HYDERABAD - 500 030.

JULY, 1992

CERTIFICATE

Mr. V.D.V.N.H. KUMAR has satisfactorily prosecuted the course of research and that the thesis entitled **ECOLOGY AND CONTROL OF KEY PESTS OF CABBAGE** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.



(Dr. T. VINOD KUMAR SINGH)

Chairman of the Advisory Committee

Date : 28/07/1992

CERTIFICATE


This is to certify that the thesis entitled **ECOLOGY AND CONTROL OF KEY PESTS OF CABBAGE** submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the Andhra Pradesh Agricultural University, Hyderabad is a record of the bonafide research work carried out by **V.D.V.N.H. KUMAR** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

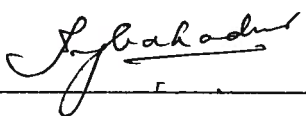
No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigation have been duly acknowledged by the author of the thesis.




(Dr. T. VINOD KUMAR SINGH)
Chairman of the Advisory Committee

Thesis approved by the Student Advisory Committee

Chairman : (Dr. T. VINOD KUMAR SINGH) 
Assistant Professor
Department of Entomology
College of Agriculture
Rajendranagar, Hyderabad.

Member : (Dr. TAJ BAHADUR GOUR) 
Associate Professor
Department of Entomology
College of Agriculture
Rajendranagar, Hyderabad.

Member : (Sri G. KRISHNAKANTH) 
Assistant Professor
Department of Statistics & Mathematics
College of Agriculture
Rajendranagar, Hyderabad.

CONTENTS

CHAPTER	TITLE	PAGE No.
I	INTRODUCTION	1 - 3
II	REVIEW OF LITERATURE	4 - 17
III	MATERIALS AND METHODS	18 - 32
IV	RESULTS	33 - 167
V	DISCUSSION	168 - 180
VI	SUMMARY	181 - 184
	LITERATURE CITED	186 - 195

LIST OF TABLES

S.No.	Title	Page No.
1.	Incidence of the aphid <u>B. brassicae</u> on two cabbage varieties at different planting dates	34
2.	Incidence of diamond back moth (DBM) on two cabbage varieties at different planting dates	40
3.	Incidence of <u>H. undalis</u> and <u>C. binotalis</u> on two cabbage varieties	45
4.	Correlation and regression between weather parameters with cabbage aphid incidence on two cabbage varieties at different dates of planting	54
5.	Correlation and regression between weather parameters with DBM incidence on two cabbage varieties at different dates of planting	56
6.	Correlation and regression between weather parameters with cabbage head bores and cabbage leaf webber on two cabbage varieties	59
7.	Multiple linear regression interaction of cabbage aphid incidence on two cabbage varieties and weather parameters	62
8.	Multiple linear regression interaction of DBM incidence on two cabbage varieties and weather parameters	64
9.	Multiple linear regression interaction of cabbage head borer and leaf webber incidence on two cabbage varieties and weather parameters	65
10.a	Step Down Regression analysis of different pests of cabbage on variety Golden Acre Planted at different dates	67
10.b	Step down Regression analysis of different pests of cabbage on variety Pride of India Planted at different dates	68
11.	Weekly mean (\bar{x}) and variance (S^2) of the cabbage aphid <u>B. brassicae</u> in variety Golden Acre	73
12.	Weekly mean (\bar{x}) and variance (S^2) of cabbage aphid <u>B. brassicae</u> in variety Pride of India	74
13.	Weekly mean (\bar{x}) and variance (S^2) of the DBM on variety Golden Acre	76
14.	Weekly mean (\bar{x}) and variance (S^2) of the DBM on variety Pride of India	77
15.	Weekly mean (\bar{x}) and variance (S^2) of <u>Hellula</u> on two cabbage varieties	79

Contd....

List of Tables contd...

S.No.	Title	Page No.
16.	Weekly mean (\bar{x}) and variance (S^2) of <u>Crocidolomia</u> on two cabbage varieties	80
17.	Dispersion parameter(k) by Trial and Error method for cabbage aphid in different plantings	82
18.	Dispersion parameters (k) by Trial and Error method for DBM in different plantings	86
19.	Dispersion parameters (k) by Trial and Error method for cabbage head borer	87
20.	Estimation of index of dispersion (I) of cabbage aphid on two varieties at three different plantings	116
21.	Estimation of index of dispersion (I) of DBM on two varieties at three different plantings	117
22.	Estimation of index of dispersion (I) of cabbage head borer and cabbage leaf webber on two cabbage varieties	119
23.	David and Moore's index of dispersion for cabbage aphid in different plantings	121
24.	David and Moore's index of dispersion for DBM in different pantings	122
25.	David and Moore's index of dispersion for <u>Hellula</u> and <u>Crocidolomia</u>	123
26.	Morista's index of dispersion (I) F_0 , d, f and tabulated value of χ^2 to measure the dispersion parameter of cabbage aphid	125
27.	Morista's index of dispersion (I), F_0 , d, f and tabulated value of χ^2 to measure the dispersion parameter of <u>Hellula</u> and <u>Crocidolomia</u>	127
28.	Morista's index of dispersion (I), F_0 , d, f and tabulated value of χ^2 to measure the dispersion parameter of <u>Hellula</u> and <u>Crocidolomia</u>	130
29.	Taylor's power law regressions for different pests of cabbage	133
30.	Lloyd's index of mean crowding for aphids in different plantings	137
31.	Lloyd's index of mean crowding for DBM in different plantings	138
32.	Lloyd's index of mean crowding for <u>Hellula</u> and <u>Crocidolomia</u>	139

Contd ...

S.No.	Title	Page No.
33.	Mean, variance and K_3 in early plantings of cabbage aphid	141
34.	Standard Error Mean and Relative variation of aphid in early planting	146
35.	Lloyd's index of mean crowding for cabbage aphids in three plantings	148
36.	Mean, variance and K_3 in normal plantings of cabbage-aphid	150
37.	Standard Error Mean and Relative variation of aphids in normal plantings	156
38.	Mean, variance and K_3 in late plantings of cabbage aphid	158
39.	Standard Error Mean and Relative Variation of aphid in late planting	163
40.	Effect of different treatment schedules on yield of cabbage crop	165
41.	Efficiency of insecticidal treatments against cabbage aphid-cost-benefit ratio	167

· LIST OF FIGURES

S.No.	Title	Page No
1.	a. Mean number of aphids in Early planting	35
	b. Mean number of aphids in Normal planting	37
	c. Mean number of aphids in Late planting	38
2.	a. Mean number of DBM in Early planting	41
	b. Mean number of DBM in Normal planting	42
	c. Mean number of DBM in Late planting	44
3.	Mean number of <u>Hellula</u> in Early planting	46
4.	Mean number of <u>Crociodomia</u> in Early planting	47
5.	Superimposition technique for aphids	49
6.	Superimposition technique for DBM	50
7.	Superimposition technique for <u>Hellula</u> and <u>Crociodomia</u>	52
8.	a. Dispersion parameter 'k' for aphid (Var. Golden Acre)	83
	b. Dispersion parameter 'k' for aphid (Var. Pride of India)	84
9.	a. Dispersion parameter 'k' for DBM (Var. Golden Acre)	88
	b. Dispersion parameter 'k' for DBM (Var. Pride of India)	89
10.	Dispersion parameter 'k' for <u>Hellula</u>	90
11.	Dispersion parameter 'k' for <u>Crociodomia</u>	91
12.	Regression line of 'y' on 'x' for cabbage aphid	93
13.	a. Relation of 1/k to mean (\bar{x}) for cabbage aphid in early planting (Var. Golden Acre)	96
	b. Relation of 1/k to mean (\bar{x}) for cabbage aphid in early planting (var. Pride of India)	97
	c. Relation of 1/k to mean \bar{x} for cabbage aphid in normal planting (Var. Golden Acre)	98
	d. Relation of 1/k to mean \bar{x} for cabbage aphid in normal planting (var. Pride of India)	99
	e. Relation of 1/k to mean \bar{x} for cabbage aphid in late planting (var. Golden Acre)	100
	f. Relation of 1/k to mean \bar{x} for cabbage aphid in late planting (var. Pride of India)	101
14.	Regression line of 'y' on 'x' for DBM	102
15.	a. Relation of 1/k to mean \bar{x} for DBM in early planting (Var. Golden Acre)	104
	b. Relation of 1/k to mean \bar{x} for DBM in early planting (Var. Pride of India)	105

Contd....

List of Figures ... Contd...

S.No.	Title	Page No
	c. Relation of $1/k$ to mean \bar{x} for DBM in normal planting (Var. Golden Acre)	106
	d. Relation of $1/k$ to mean \bar{x} for DBM in normal planting (Var. Pride of India)	107
	e. Relation of $1/k$ to mean \bar{x} for DBM in late planting (Var. Golden acre)	108
	f. Relation to $1/k$ to mean \bar{x} for DBM in late planting (Var. Pride of India)	109
16.	a. Relation of $1/k$ to mean \bar{x} for <u>Hellula</u> on Var. Golden Acre	110
	b. Relation of $1/k$ to mean \bar{x} for <u>Hellula</u> on Var. Pride of India	111
	c. Relation of $1/k$ to mean \bar{x} for <u>Crocidolomia</u> on var. Golden Acre	112
	d. Relation of $1/k$ to mean \bar{x} for <u>Crocidolomia</u> on Var. Pride of India	113
17.	Taylor's Power Law for aphid	135
18.	a. Mean and variance of aphid on top stratum on Golden Acre in Early planting	142
	b. Mean and variance of aphid on middle stratum on Golden Acre in Early planting	143
	c. Mean and variance of aphid on bottom stratum on Golden Acre in Early planting	144
19.	Dispersion parameter 'k' for cabbage aphid on different strata in Early planting	145
20.	a. Mean and variance of aphid on top stratum on Golden Acre in Normal planting	151
	b. Mean and variance of aphid on middle stratum on Golden Acre in Normal Planting	152
	c. Mean and variance of aphid on bottom stratum on Golden Acre in Normal planting	153
21.	Dispersion parameter 'k' for cabbage aphid on different strata in normal planting	154
22.	a. Mean and variance of aphid on top stratum on Golden Acre in late planting	159

contd...

List of Figures contd....

S.No.	Title	Page No
b.	Mean and variance of aphid on middle stratum on Golden Acre in late planting	160
c.	Mean and variance of aphid on bottom stratum on Golden Acre in late planting	161
23.	Dispersion parameter 'k' for cabbage aphid on different strata in Late planting	162.

ACKNOWLEDGEMENTS

In all sincerity and pleasure, I would like to thank **Dr. T. Vinod Kumar Singh**, Assistant Professor, Department of Entomology, College of Agriculture, Rajendranagar and Chairman of my Advisory Committee, for his constant encouragement, cooperation and providing necessary facilities during the course of this study.

I am indebted to **Dr. C. Subba Rao**, formerly Professor and Head of the Department of Entomology, College of Agriculture, Rajendranagar for his keen interest, constant advice and for his words of encouragement during the present study.

I am grateful to **Dr. D.D.R. Reddy**, Head of the Department, College of Agriculture, Rajendranagar for going through the document and suggesting corrections wherever need be. I am also thankful to him for providing all the facilities needed to accomplish the present study.

I am grateful to **Dr. T.B. Gour**, Associate Professor, Department of Entomology, College of Agriculture, Rajendranagar for his timely and valuable suggestions during the present study.

I would like to place on record my sincere gratitude to **Sri G. Krishnakanth**, Assistant Professor, College of Agriculture, Rajendranagar for his timely counsel, valuable suggestions during interpretation of the results.

I would like to express my profound sense of gratitude to **Dr. Raman Goud, Dr. Sreeramulu, Dr. Ramesh Babu, Mr. Satyanarayana Murthy, Mr. Manmohan Singh, Dr. Subbaratnam, Dr. Sreenivas Rao, Dr. Sudheer Reddy, Dr. Dharma Reddy** and **Mrs. Sarwath** and other members of the Faculty for helping me at different stages of the experiment and thesis writing.

Thanks are also due to **Mr. D.S.R. Raju**, for helping me in analyzing the data statistically.

My parents and family have always been a constant driving force behind me and I thank them for what they have been to me.

I am also indebted to my colleagues in the department and friends in the College, whose help I do not wish to quantify as it would be unwise of me.

Finally, the financial assistance provided by the State Government is highly acknowledged.


V. D. V. N. H. Kumar.

(V.D.V.N.H. KUMAR)

DECLARATION

I, V.D.V.N.H. KUMAR, hereby declare that the thesis entitled ECOLOGY AND CONTROL OF KEY PESTS OF CABBAGE is a result of the original research done by me. I further declare that the thesis or any part thereof has not been published earlier in any manner.

Date :


(V.D.V.N.H. KUMAR)

Name of the student : V.D.V.N.H. KUMAR
Title of the thesis : ECOLOGY AND CONTROL OF KEY PESTS OF
CABBAGE
Degree for which it : MASTER OF SCIENCE IN AGRICULTURE
is submitted
Major field of study : ENTOMOLOGY
Major advisor : Dr. T.V.K. SINGH
Name of the : ANDHRA PRADESH AGRICULTURAL UNIVERSITY
University
Year of submission : 1992

ABSTRACT

Studies conducted during 1991-92 on "ECOLOGY AND CONTROL OF KEY PESTS OF CABBAGE" were undertaken at Students' Farm, College of Agriculture, Rajendranagar, Hyderabad included the seasonal incidence, effect of abiotic factors on population build-up, distribution studies of cabbage aphid (Brevicoryne brassicae L.), diamond-back moth (Plutella xylostella L.), cabbage head borer (Hellula undalis F.) and cabbage leaf webber (Crocidolomia binotalis Zeller) on Golden Acre and Pride of India in three plantings; intra-plant distribution of aphid on variety Golden Acre and yield-infestation studies.

Among the three plantings, the incidence of aphid, Hellula and Crocidolomia was maximum in early planted crop (August). The incidence of DBM was maximum in the late planted (December) crop. Among the two varieties Pride of India harboured more individuals than Golden Acre. None of the abiotic factors influenced the population build-up of these pests in a set trend.

The distribution studies were carried out for all these pests and it was found that the variance was greater than mean in all the weeks of observation indicating a negative binomial distribution. The distribution pattern was further confirmed by calculating the dispersion parameter 'K' which was less than '8'. Other indices of dispersion were computed which confirmed the aggregated or contagious nature of dispersion of these pests.

The intra-plant distribution studies on aphids revealed that on each of the three strata i.e., top, middle and bottom, the pest followed a negative binomial distribution, which was

confirmed by computing the dispersion parameter 'K' by trial and error method and various indices. The top strata was found to harbour more number of aphids compared to other two strata.

Among various treatments maximum protection treatment gave the best control and highest yields. When the cost-benefit ratio was calculated the Farmer's Practice II gave a better cost-benefit ratio.

...

CHAPTER I

INTRODUCTION

Vegetables form the important component of a balanced diet. India is the world's second largest producer of vegetables next to China. The annual production is estimated around 45 million tonnes from a cropped area of four million hectares which is around 2.5 to 3 per cent of the total cropped area. Among the various vegetables grown in India, cole crops form a major group of vegetables. The commercially important crops of this group are cauliflower, cabbage, knol-knol and radish. The cabbage is the second most popular vegetable of the cole group. The productivity of cabbage in India is to the tune of 5.07 tonnes ha. This is in contrast to the average world productivity of 21.62 tonnes ha⁻¹ (Kirti Singh, 1991). The important constraint for its low productivity is the high incidence of a wide variety of pests.

Cabbage is ravaged by a wide number of pests, of which diamond-back moth, Plutella xylostella L., cabbage leaf webber, Crociodolomia binotalis Zell., cabbage borer, Hellula undalis F., tobacco caterpillar, Spodoptera litura Fab., green peach aphid, Myzus persicae Sulz., and cabbage aphid, Brevicoryne brassicae L. are most important (Mac Gillivray, 1961). Among these pests, the aphids are found to attack the crop through out the cropping season by sucking the plant sap. The lepidopterous larvae attack the crop by feeding on the leaves. After the head formation the

larvae attain a greater proportions and reduce the yields by boring into the head and feeding.

Eventhough lot of work has been undertaken on the seasonal incidence of cabbage pests by Abraham and Padmanabhan (1967) in Tamil Nadu, Sachan and Srivastava (1972) in Rajasthan and Khaire et al. (1987) in Maharashtra, no concerted work was done in Andhra Pradesh. The incidence of these pests also differs with the variety grown in a agro-ecosystem. The ecological aspects of the pests remained unexplored, therefore an understanding of the dispersion of pests in space and the intra-plant distribution is vital as it affects the sampling, particularly the number of samples required for estimating the population density, and the pattern of sampling. Similarly, no work has been done in past with regard to cost - benefit ratios using different practices. Therefore, experiments have been designed with view to fill up these lacunae in the management of cabbage pests with the following objectives.

1. To study the incidence of different pests of cabbage at different planting dates and the impact of abiotic factors on the pest population buildup in cabbage.
2. To investigate the spatial distribution of different pests of cabbage and to test various indices of dispersion.

3. To understand the intra-plant distribution of cabbage aphid, a key pest of cabbage.
4. To work out the effect of different treatment schedules and cost- benefit ratio .

...

CHAPTER II

REVIEW OF LITERATURE

Cabbage is subjected to attack by a variety of insect pests. Studies on "Ecology and control of key pests of cabbage" are very limited and the review of literature on seasonal incidence of pests of cabbage, their spatial distribution with indices of dispersion, intra-plant distribution and studies on chemical control are presented.

2.1 SEASONAL INCIDENCE OF CABBAGE PESTS

Aphids

Herakly and El-Ezz (1970) reported that peak numbers of cabbage aphid, Brevicorye brassicae (L.) occurred in July-August, though the pest was present throughout the year on cabbage in Egypt. Dhaliwal and Goma (1979) noticed high incidence of the aphid B. brassicae during 1973-74 from mid-February to April on cabbage at Solan. At Himachal Pradesh during 1979-81 a population peak of B. brassicae was observed on the seed cauliflower crop at a thermal constant of 688 day-degrees celsius above a threshold of 5°C. The aphid population was greatly reduced by heavy rainfall, wind, frost and other biotic factors in February-March, 1981 (Kotwal and Bhalla, 1983).

Khair et al. (1987) reported the peak aphid incidence in the second fortnight of March in a study carried out in Maharashtra, in 1982 through 1984. At Meghalaya, the cabbage

aphid was active from November to April (Sachan and Gangawar, 1990). However, that under Hyderabad conditions the maximum incidence of aphid was found in October and November planted crops with peak populations at the end of November and January months, respectively (Padmavathi, 1991).

Diamond-back moth

The development and survival of diamond-back moth, Plutella maculipennis (Curt.) was slightly influenced by atmospheric humidity but temperature had considerable effect on all its stages (Lal, 1939). The minimum threshold of development was found to be 10°C and the upper vital limit 40°C. Abraham and Padmanabhan (1967) found it on cruciferous vegetables in high proportion in Tamil Nadu during the hot weather period, especially, in April and May with as many as 32 caterpillars on a plant in which, not a single leaf was left untouched. The population peak continued high till the month of August and was low during the months of November to February.

Sachan and Srivastava (1972) in their studies on seasonal incidence of Plutella xylostella (L.) on cabbage in Rajasthan, found seven to eight per cent of the plants infested in September-October when infestation started and 32-100 per cent in January-March at the peak. At Taiwan, Chin (1974) observed that the populations of P. xylostella were highest in March and October and lowest in June-August. He also reported that relative humidity did not affect pest populations. Bindra et al. (1977) in

their population fluctuation studies on cauliflower at Ludhiana, India during 1973-74 and 1974-75 found that the maximum activity of the pest was during August-September months. During January-February reduction in the population build-up was observed as the season became warm.

Harinath Babu (1985) reported that Plutella larvae were found damaging the crop at Hyderabad (Andhra Pradesh) from early November till end of January with peak activity during late November. Occurrence of population peaks of DBM in February-April and November has been observed in Singapore (Ong and Soon, 1989). Recently, Padmavathi (1991) found high populations in November planted crop at Hyderabad.

Talekar and Lee (1985) reported that heavy infestations of P. xylostella on cabbage occurred mainly in the cool dry months, in Taiwan. Gera and Bhatnagar (1992) observed the maximum population of diamond-back moth in first week of February at Jobner, Rajasthan.

Hellula

Hellula undalis (F.) has been reported to be active from July-August to October-November, causing serious damage to cabbage and radish in Japan (Watanabe, 1927; Ishi, 1938). In Madhya Pradesh, Rawat et al. (1968) found that the cabbage borer was active on cabbage and cauliflower during March to July and declined during the winter.

Initial infestation of it on cabbage and radish started in July and populations increased rapidly from August to October, in Central Japan. High temperatures and low precipitations in August especially led to an increase in populations after September (Yamada, 1981). In Karnataka, the peak activity of H. undalis on cabbage was found from January to April (Peter et al., 1987).

Crocidolomia

Fagoonee (1980) attributed rainfall as the main factor regulating the populations of Crocidolomia binotalis (Zell.) on cabbage, in Mauritius. He observed that during periods of low rainfall, populations multiplied rapidly at 20-40°C, but during heavy rainfall, population density was very low. C. binotalis occurred nearly all the year round, but was numerous from May to December with a peak in November (Lee, 1986).

2.2 SPATIAL DISTRIBUTION OF INSECTS

The manner in which the members of a pest population are distributed in space is known as the 'distribution pattern' or the 'dispersion of the population'. Dispersion is different from dispersal, which usually means the movement of individuals away from the population.

Spatial distribution is one of the most important characteristics of ecological significance, unlike rates of growth and reproduction, which often vary more between genera-

tions within a species than they do between species. The spatial pattern of an insect is of specific interest in both applied and fundamental studies.

Some insect species reproduce so rapidly that population density can change greatly during the course of field experiment. An understanding of the dispersion is also vital in the analysis of predator-prey and host-parasite relationships (Anderson, 1974; Hassel and May, 1974).

Theoretically the individuals of a population can follow three basic types of spatial distribution. These are as follows:

- (i) A random distribution
- (ii) A regular distribution or under dispersion or uniform distribution or even distribution. Regularity is a spatial condition with more equal spacing of individuals than that occurs at random.
- (iii) A contagious distribution or overdispersion or clumped distribution or aggregated distribution. "Contagious" means influencing each other's distribution.

Aggregation is a spatial condition in which density is more locally condensed than at random. It has no implication of causation. To 'congregate' means to collect together actively. Contagious means influencing each others distribution (Taylor, 1984).

Most of the workers have described the natural insect populations with negative binomial model (Anscombe, 1948; Harcourt, 1960, 1961, 1963a&b, 1965, 1967; Lyons, 1964; Ibarra et al., 1965; Morris, 1955, 1960). Thus, there are reasons for expecting organisms to be aggregated.

The distribution of diamond back moth on Brassica spp. was investigated in Malaysia. The adult had a random distribution while the pre-adult stage had a negative binomial distribution. Adults and eggs were found mainly on the upper leaf surface and larvae (except for the first instar), and pupae on lower surface. The larvae tend to aggregate after hatching and during pupation, although they dispersed during the period in between (Cha and Lim, 1979). Similarly, field studies in Karnataka, India during winter 1985, the DBM larvae showed a random distribution during the early stages of infestation, but later their distribution became aggregated. Larvae of C. binotalis had an aggregated distribution throughout crop growth (Srinivasan and Rao, 1987).

The negative binomial ($S^2 > X$) is often used for contagious or aggregated distributions, but is only one of several possible choices (Elliott, 1977). Many contagious insect populations that have been studied can be adequately expressed by this distribution (Bliss and Owen, 1958; Harcourt, 1965; Safranyik and Raski, 1970; Allen et al., 1972; Kogan et al., 1974; Latheef and Pass, 1974; Clement and Christensen, 1979; Suman and Wahi, 1981; Wilson et al., 1983; Singh, 1989; Singh, 1991).

The negative binomial series is characterised by or reflects a variation in the expectation of counts in the observational units, this expectation varying in a distribution proportional to that of chi-square. It has two parameters, the mean (X) and an exponent (' K '), which is a measure of dispersion or aggregation.

Its values can range from zero, where aggregation is extreme to infinity, which defines a purely random distribution of counts. The value of ' K ' is not constant for a population, but often increases with mean (Anscombe, 1948; Bliss and Owen, 1958). Generally, the value of ' K ' for negative binomial are below 8, as they become larger the distribution approaches and is eventually identical with that of Poisson when ' K ' approaches infinity (Southwood, 1978).

Studies on the negative binomial distribution of key pests of cabbage are negligible but literature is available on the mustard aphid (Parasnath and Mishra, 1986; Mahal et al., 1988) Thrips tabaci (Suman et al., 1980a; and Srinivasan et al., 1981).

Calculation ' K ' of the negative binomial

Anscombe (1949, 1950); Bliss and Fisher (1953); De bauche (1962); Katti and Gurland (1962) and Legay (1963) have computed the value of ' K ' by several methods. Most commonly used methods are by movement estimate of ' K ', estimation of ' K ' from

proportion of zeroes and maximum likelihood method of 'K' estimation by Trial and Error Method (Southwood, 1978).

The "goodness of fit" is tested by χ^2 (Chi-square) test by comparing the observed and expected frequencies (Bliss and Fisher, 1953) or by second and third moment as described by Southwood (1978).

2.3 INDICES OF DISPERSION

The "goodness-of-fit" can also be tested by other indices of dispersion based on Mean and variance ratio (Patil and Stiteler, 1974), Cole's index (Cole, 1946), David and Moore index (David and Moore, 1954), Reciprocal of exponent 'K' (Elliott, 1979), Morista's index of dispersion (Morista, 1962), Lloyd's index of mean crowding (Lloyd, 1967), Lloyd's patchiness index (Lloyd, 1967), Taylor's power law (Taylor et al., 1978) and Iwao's patchiness regression (Iwao, 1968).

Taylor's Power law has been made use to study spatial distribution of insect species by Hayman and Lowe (1961) for cabbage aphids, Evans (1972) for Aeneolamia varia saccharina and A. postica jugata, Dean (1973) for aphids, Metapolophium dirhodum (Walker) and M. festucae (Theobald) and Sitobion avenae (Fab.), Kogan et al. (1974) for bean leaf beetle and Pieters and Sterling (1974) for cotton flea hopper.

Trumble (1982) calculated Lloyd's index to estimate within field distribution of aphids on broccoli and concluded

that at low population level aphids were aggregated but as aphid density increased distribution became random. Therefore, sampling techniques used for scouting aphid population should be designed to account for a change in distribution as aphid populations increase.

Prasad (1952), collected aphid (L. erysimi) data on mustard crop on the basis of plants combined in various ways giving composite units of different shapes and sizes. A dot-diagram showing the distribution of the number of aphids in the field revealed that the aphids were not uniformly distributed over the different portions of the field but were in patches of varying density.

Chua and Lim (1977) studied the effect of interplant distance on the distribution pattern of diamond back moth. Adults were found to have a random distribution while the immature stages had a aggregated distribution viz., negative binomial distribution.

Chua and Lim (1979) studied the distribution of all stages of P. xylostella on choy-sum plants. The adult had a random distribution while the pre-adult stage had a negative binomial (aggregated) distribution. The larvae tended to aggregate after hatching and during pupation, although they dispersed during the period in between.

2.4 INTRA-PLANT DISTRIBUTION OF INSECT POPULATIONS

The within-plant distribution of an insect indicates preference for various plant parts or the mobility of the pest on a host. From an applied aspect, this information indicated the synchrony of a pest with its host plant, aids in the development of sampling procedures. It enables prediction of when an economic threshold will be reached and helps in selection of appropriate application methods for effective control. The literature reveals that intra plant distribution of insect pests of cabbage has not been studied very extensively.

Suman et al. (1980) studied the distribution pattern of cabbage leaf webber, C. binotalis on cabbage. Various statistical tests showed that the population exhibited an aggregative nature and a negative binomial distribution.

The spatial distribution of larvae of P. xylostella on cauliflower could be adequately described by the negative binomial. The relationship between the variance and mean confirmed to Taylor's Power law, where 'b' was 1.41. The mean crowding-mean relationship was significantly linear. Larvae were distributed among plants in an aggregated pattern, with a clumping unit of 2.4 larvae per plant. No constant value of 'K' was detected over a density range of 0.37 - 17.93 larvae per plant and $1/k$ increased suddenly at low density and declined gradually towards higher density (Chen and Su, 1986).

2.5 STUDIES ON CHEMICAL CONTROL

Ho (1965) showed that in spray tests with chlorinated-hydrocarbon insecticides, applications at four day intervals of endrin and isobenzan (Telodrin) at 0.025 per cent toxicant and endosulfan (Thiodan) at 0.15 per cent were found to be the most effective against Plutella larvae.

Tandon and Bhalla (1977) found that application of granular systemic insecticides through soil like phorate, dimethoate or disulfotam at 1.8 kg ha^{-1} in early February effectively controlled infestation by B. brassicae, the most important pest of the cabbage crop for 6-8 weeks. Since the crop requires protection until May, a second application to the soil, or a foliar treatment, may also be necessary to provide adequate control until harvest.

Krishnaiah et al. (1979) evaluated 13 insecticides for their effectiveness against P. xylostella and 17 against C. binotalis on cabbage by applying biweekly sprays. It was found that quinalphos, chlorpyrifos and dioxathion applied at the rate of $0.5 \text{ kg a.i. ha}^{-1}$, followed by monocrotophos (0.3 kg); phosalone, phenthoate and methomyl (0.5 kg) were effective against P. xylostella. Monocrotophos (0.3 kg), quinalphos, phenthoate, chlorpyrifos, chlorfenvinphos, trichlorphon, acephate, methamidophos (0.5 kg), fenitrothion (0.75 kg) and endosulfan (0.7 kg) proved effective against C. binotalis.

Mohan et al. (1981) tested 19 insecticides against L. erysimi and C. binotalis. These were applied at an interval of 7 or 14 days in the field. Methamidophos at 0.25 or 0.5 kg ha⁻¹ gave excellent control of both pests; of the remaining insecticides quinolphos, endosulfan, ethiofencarb and pirimicarb were the most effective against L. erysimi alone and fenvalerate, permethrin and methamidophos against C. binotalis alone.

Gandhale et al. (1982) studied the effectiveness of sprays containing endosulfan, quinalphos, fenitrothion, phosalone and malathion at 0.05 per cent and formothion and thiometon (0.02) against B. brassicae on cabbage. The highest mortality was caused by thiometon (77.28%), while malathion was least effective (62.48% mortality). The mortalities caused by the remaining treatments ranged from 71.50 to 76.57 per cent.

Krishnaiah and Mohan (1983) tested the effectiveness of several chemical and biological insecticides against P. xylostella, C. binotalis, L. erysimi and M. persicae on cabbage. Quinalphos, methamidophos, dioxathion and endosulfan gave effective control of P. xylostella for two weeks, while Bacillus thuringiensis var. Kurstaki (Dipel), a mixture of Dipel and chlordimeform (chlorphenamidine), monocrotophos, phosalone, phenthoate, methomyl and malathion suppressed the population for one week; garlic oil gave moderate control of the pest. C. binotalis was controlled effectively for two weeks by monocrotophos, quinolphos, phenthoate, chlorpyrifos, chlorfenvinphos, acephate,

methamidophos, fenitrothion, carbaryl and endosulfan. Applications of monocrotophos, quinalphos, methamidophos, chlorpyrifos and endosulfan controlled L. erysimi for two weeks. M. persicae was controlled only with methamidophos and quinalphos for two weeks and with endosulfan for one week.

Sarode and Kumar (1983) studied the efficacy of some granular insecticides against major pests of cabbage i.e., P. xylostella and L. erysimi. The most effective against both pests was carbofuran at 1.5 kg ha^{-1} , followed by phorate at 1.5 kg . Granular treatment of cabbage plants needed another control measure 45 days after transplanting.

Mohite and Moholkar (1988) reported that when 0.05 per cent monocrotophos, fenitrothion or endosulfan, 0.03 per cent quinalphos and bromophos; 0.02 per cent phosphamidon, dichlorvos, demeton-methyl or dimethoate was applied in sprays to cabbage in the field, the population of aphid B. brassicae was reduced by 91.72 to 97.59 per cent in 48 hours as compared to 10.08 per cent for no insecticide. Monocrotophos and phosphamidon afforded the best control of the aphid.

Yadav et al. (1988) observed that methyl-demeton and endosulfan gave excellent kill and kept the cabbage aphid population under check for a longer period while malathion and chlorpyrifos were observed equally effective upto eight days of spraying. Carbaryl gave less kill of aphid closely followed by dichlorvos. Other insecticides were found moderately effective.

Padmavathi (1991) reported that the combination treatments of diflubenzuron 0.025 per cent with acephate 0.075 per cent or triazophos 0.06 per cent were found highly effective in controlling insect pests of cabbage, followed by individual treatments of triazophos 0.06 per cent and acephate 0.075 per cent.

...

CHAPTER III

MATERIALS AND METHODS

The present investigations on the "Ecological aspects of key pests of cabbage (Brassica oleracea L. var. capitata L.)" were carried out in three plantings namely, early (August) normal (October) and late (December) at Student's Farm, College of Agriculture, Rajendranagar, Hyderabad during the year 1991-92.

The geographical location is 17°19' North latitude and 78°28' of East longitude. It lies at an altitude of 543 m above the mean sea level. The climate of the experimental site is tropical, semi-arid dry with an annual mean rainfall of 764.4 mm and annual mean potential evaporation of 1756.8 mm (Rao et al., 1971).

Layout and sowing

Two popular varieties Golden Acre and Pride of India of cabbage were used for studying the incidence of the pest planted at different planting dates and distribution experiments, whereas, Golden Acre alone was used for studying the intra-plant distribution and studies on chemical control.

Cabbage nursery was raised on well prepared raised seed beds. The seed bed was drenched with Blitox at 3 g l⁻¹ to minimise the damping off disease. The seeds were sown (650 g ha⁻¹) in lines and were watered with rose cans once in two days. To ensure good growth of the seedlings, the soil was mixed with FYM and

urea. After 30 days the seedlings were transplanted to the main field.

The main field (Red sandy loams) was ploughed thrice, disced twice and levelled prior to sowing. Farm yard manure @ 20 tonnes ha⁻¹ was spread uniformly in the field before third ploughing and the plantings of the two varieties were taken up. The recommended fertilizer dose of 120 N, 80 P₂O₅ and 40 K₂O kg ha⁻¹ were applied in the form of urea, single superphosphate and muriate of potash, respectively. Half the dose of nitrogen and entire dose of phosphorus and potash were applied as basal and the remaining nitrogen was applied a month after planting. Hand weeding was done periodically to keep the field weed free. Irrigations were given as and when the plots were found dry. The different plantings dates during the period of study are:

Sowing, transplanting and harvesting periods of cabbage

	Nursery raising	Transplanting	Harvest
Early planting	15th July, 1991	15th August, 1991	1st December 1991
Normal planting	15th September, 1991	15th October, 1991	15th January 1992
Late planting	15th November, 1991	15 December, 1991	15th March, 1992

Experimental details

For Dispersion studies in each planting

Crop : Cabbage
 Variety : Golden Acre and Pride of India
 Plantings : Early, Normal and Late

Blocks : Ten (5 for each variety)
Block size : 8 x 4 m
Quadrats in : 5
each block
Total number : 25
of quadrats

For chemical control studies

Crop : Cabbage
Variety : Golden Acre
Planting : Normal
Design : Randomized Block Design
Treatments : 6
Replications : 4
Plot size : 5 m x 4 m

Meteorological data

The data on weather parameters like maximum and minimum temperature, relative humidity and rainfall during the experimental period were obtained from the Meteorological Observatory, Agricultural Research Institute, Rajendranagar and are provided in Appendix I.

3.1 INCIDENCE OF PESTS

The incidence of the pests occurring on cabbage from transplanting to harvest during the period of study are presented below.

Common Name	Scientific Name	Family/order
1. Cabbage Aphid	<u>Brevicoryne brassica</u> (Linn.)	Aphididae/ Homoptera
2. Diamond-back moth	<u>Plutella xylostella</u> (L.)	Yponomeutidae/ Lepidoptera
3. Cabbage head borer	<u>Hellula undalis</u> (F.)	Pyralidae/ Lepidoptera
4. Leaf webber	<u>Crocidolomia binotalis</u> (Zeller)	Pyralidae/ Lepidoptera

The species of the aphid was identified by preparing permanent slides following the method adopted by Blackman and Eastop (1984). For identification of lepidopterous pests infesting cabbage, larvae were reared on natural host in the lab. After adult emergence they were identified using the keys of Emmett (1980).

3.2 POPULATION BUILD-UP

To study the influence of abiotic factors on different pests, two approaches were used. First, graphical superimposition technique was employed to study the effect of meteorological variables prevailing in the preceding periods on the pest incidence. Secondly, to study the effect of different weather parameter, simple linear correlation coefficients were calculated. In order to find out the combined effect of weather factors influencing the incidence of pests, multiple regression analysis and step down regression analysis was done. This procedure was applied to overcome the effect of probable inter correlations among the weather variables (which are the independent variables).

3.3 DISTRIBUTION STUDIES

For each planting the crop was raised in an area of 320 m². The entire area was divided into ten plots with five plots for raising the variety Golden Acre and the rest with the variety Pride of India. Observations of different pests of cabbage were taken on 25 randomly selected plants from each of the quadrat in individual variety at weekly intervals from the time of transplanting.

The population of the aphids (Plate-1) was recorded by selecting 25 plants one from each quadrat at random counts included both nymphs and adults. The larval counts of diamond back moth Plutella xylostella (L.) (Plate 2) were recorded from 25 plants selected randomly from each quadrat. Similarly 25 plant counts were also taken for leaf webber, Crocidolomia binotalis Zeller (Plate 3) and cabbage head borer H. undalis (F.).

3.3.1 Frequency distribution

The first step in ascertaining the nature of distribution of any pest is to arrange the data in frequency distribution. Mean (\bar{X}) and variance (S^2) were then worked out for every weekly observations following usual statistical procedures (Snedecor and Cochran, 1967). On the basis of mean and variance statistical tests were applied to confirm the distribution of different pests of cabbage.



PLATE II: LARVA AND PUPA OF DIAMOND-BACK MOTH ON CABBAGE



PLATE III: LARVA OF CABBAGE HEAD BORER

3.3.2 Determination of dispersion parameter 'k'

The first step was calculation of dispersion parameter K (Moment estimate of K) for all the weekly observations by using the formula of Elliott (1979).

$$K = (\bar{X})^2 / S^2 - \bar{X}$$

Other methods of calculating 'k' (Southwood, 1978) which are employed were:

'k' from proportion of zeroes was estimated by using

$$\text{Log } (N/n_0) = k \log [1 + (\bar{x}/k)]$$

Trial and error (Iterative) method was employed to calculate 'K' by the following formula:

$$N \log_e \left(1 + \frac{\bar{x}}{k}\right) = \sum \left(\frac{Ax}{k+\bar{x}}\right)$$

The value of 'k' obtained by this method is alone mentioned in results and is used for all further calculations and was treated as real and accurate 'k' value (Southwood, 1978) for all practical purposes.

3.3.3 Determination of common 'k' (K_c)

The common value of 'k' during experimental period was computed by following moment and regression method of Bliss (1958) and Bliss and Owen (1958). The two statistics required were calculated as follows:

$$x' = (\bar{x})^2 - \frac{s^2}{N}$$

$$y' = s^2 - \bar{x}$$

The common 'k' (K_c) was given by $K_c = \frac{\sum x'}{\sum y'}$

The common 'K' value was calculated separately for each plantings as well as on pooled basis for three plantings. The values of 'K' below 8 indicate negative binomial or aggregated distribution (Southwood, 1978).

3.4 INDICES OF DISPERSION

The Poisson distribution, resulting from random dispersion, makes a useful yardstick by which the actual distributions are compared. As an alternative to random dispersal, insects are usually aggregated to some extent, so the scatter of the population values tend to be increased by aggregation. Many different indices have been proposed to compare the different patterns of dispersion in population. The following indices of dispersion were used to ascertain the distribution nature of the pests.

3.4.1 Variance to mean ratio or index of dispersion(I)

The test is based on the equality of variance and mean in a Poisson series (Patil and Stiteler, 1974). The variance to mean ratio, or index of dispersion (I), will approximate to unity in a true poisson expectation.

This index of dispersion will often depart from unity, a value of zero implies regular distribution and a value greater

than one implies for aggregation or contagious type of distribution.

3.4.2 David and Moore's Index of Dispersion

$$\frac{s^2}{\bar{x}} - 1$$

Data was accepted as negative binomial when it departed from zero for Poisson series.

3.4.3 Morista's index of dispersion (1962)

Morista's index was resorted to remove the effect of quadrat size on the measure of aggregation and the significance of departure from unity was tested by,

$$F_o = I_g (\sum x-1) + (n - \sum x)$$

3.4.4 Taylor's power law (Taylor et al., 1978)

A more general approach to variance - mean relationship was worked out in Taylor's Power law by the equation

$$s^2 = a + \bar{x}^{+b} \text{ or}$$

Where 'a' is a sampling factor and 'b' is a measure of aggregation, considered as constant for a species. Values of $b > 1$ indicate an aggregate distribution, $b=1$ random distribution and $b < 1$ a regular distribution.

or

$$\log s^2 = \log a + b \log \bar{x}$$

Regression of $\log S^2$ on $\log \bar{x}$ makes the relationship linear and allows the estimation of 'a' (intercept) and 'b' (slope).

3.4.5 Lloyd's Index of mean crowding (1967)

The degree of crowding experienced by an individual was worked out by

$$\bar{x}^* = \bar{x} + \left(\frac{s^2}{\bar{x}} - 1 \right)$$

3.5 INTRA-PLANT DISTRIBUTION OF APHIDS

Intra plant distribution of aphids was worked out by dividing the whole plant into three strata, upper, middle and lower and from each strata three leaves were sampled totalling to nine leaves from a single plant. The upper strata was sampled from three leaves near to the head, middle strata from middle position and bottom strata comprised of older leaves. After arranging the data in frequency distribution, mean (\bar{x}) and variance (s^2) were worked out. Dispersion parameter (k) by trial and error (Iterative) method and Lloyd's index of mean crowding was worked out as per the methods outlined earlier in distribution studies in the same chapter.

Lloyd's index of patchiness is the ratio of mean crowding (\bar{x}^*) to mean density (\bar{x}). The index of patchiness worked out as Lloyd's mean crowding index is highly correlated to the mean.

The value of index of patchiness equal to or less than unity represent binomial, while greater than unity is contagious distribution.

Iwao's patchiness regression which gives linear relationship between mean crowding and mean density over a series of densities ($\bar{x} = \alpha + \beta x$) was also worked out to know its impact on intra-plant distribution of aphid.

Iwao (1968) termed the intercept ' α ' as the index of basic contagion and slope ' β ', the density contagiousness coefficient. Positive value of ' α ' indicates a tendency to crowding and negative values, repulsion. The distribution pattern is contagious if ' β ' is > 1 and ' α ' is > 0 or ' β ' is 1 and ' α ' > 0 . The pattern is binomial if ' β ' < 1 and $\alpha = 0$ or $\beta = 1$ and $\alpha < 0$.

In order to confirm further, which stratum provides the most reliable estimate of pests density on plant, relative variation (RV) values were calculated, as a criterion of reliability (Ruesink, 1980; and Walgenbach et al., 1985).

The paired 't' test was also employed to know the significance among different strata.

3.6 STUDIES ON CHEMICAL CONTROL

To carryout the studies on control aspects of cabbage pests, different treatment schedules were formulated as given below. The experiment was carried in a simple randomized block

design with six treatments, which were replicated four times.
The plot size was 5 x 4 m.

The various treatments used are :

- T₁ Untreated control
- T₂ Maximum protection treatment
i.e. 8 kg/ha carbofuran at the time of nursery + 8 kg/ha
carbofuran at the time of transplanting as basal +
acephate 0.75 per cent spray 4 times at every 15 days
interval.
- T₃ Need based application
As a need based application monocrotophos 0.07 per cent
was used for aphids, and synthetic pyrethroid for lepi-
dopterous larvae.
- T₄ Calender based application
Acephate 0.75 per cent was sprayed at every 15 days
interval as calender based application from 15 days
after transplanting.
- T₅ Farmer's practice (I)
First spray with Endosulphan 0.05 per cent at 15 days
and thereafter quinolphos 0.05 per cent at heading
stage.

T₆ Farmer's practice (II)

Spraying endosulphan 0.05 per cent at 15 days after transplanting and if infestation of caterpillars high spraying of synthetic pyrethroids just before harvest.

The pest population was estimated a day before the application of the spray on five plants taken at random from each treatment. Post-treatment counts were taken at 1, 3, 7 and 14 days after application.

Cost-benefit ratio

Cost-benefit ratios were calculated for all the different schedules ascertaining the market cost of pesticides, labour charges and yield in terms of rupee using the following formula:

$$\text{Cost-benefit ratio} = \frac{\text{Cost of pesticides + labour charges (Rs)}}{\text{Yield (Rs)}}$$

...

CHAPTER IV

RESULTS

4.1 PEAK INCIDENCE OF PESTS IN DIFFERENT PLANTINGS

The incidence of the aphid B. brassicae, diamond back moth P. xylostella, cabbage head borer, H. undalis and leaf webber C. binotolis on two popular varieties of cabbage viz., Golden Acre and Pride of India grown in three different plantings are presented in Tables 1 to 3.

4.1.1 Cabbage aphid (B. brassicae)

4.1.1.1 Early plantings

A perusal of the data in Table 1 and Fig. 1a indicated that in the early planting, the aphid incidence started gradually building up from second week after transplanting and attained a peak of 118.72 aphids per plant in 70 DAT (44th standard week) in var. Golden Acre and maintained a higher population for three weeks, and, thereafter aphid population declined to 36.16 aphids per plant in 47th standard week. However, population again increased to 65.52 aphids per plant in the last week of crop growth.

On the other hand, in the var. Pride of India, even though the aphid appeared at the same time (36th standard week) but the population increase was comparatively slower ranging from 1.04 to 30.20 aphids per plant. Thereafter, the population started building up and reached a peak of 125.76 aphids per plant

Table 1: Incidence of aphid B. brassicae on two cabbage varieties at different planting dates

Standard week	No. of B. brassicae/plant							
	Early planting		Normal planting		Late planting			
	Golden Acre	Pride of India	Golden Acre	Pride of India	Golden Acre	Pride of India		
35 (7)	0	0	-	-	-	-		
36 (14)	2.56	1.04	-	-	-	-		
37 (21)	5.56	3.52	-	-	-	-		
38 (28)	3.20	1.92	-	-	-	-		
39 (35)	0.80	7.60	-	-	-	-		
40 (42)	7.48	13.16	-	-	-	-		
41 (49)	12.12	20.80	-	-	-	-		
42 (56)	24.72	30.20	-	-	-	-		
43 (63)	57.20	29.16	-	-	-	-		
44 (70)	118.72	68.00	-	-	-	-		
45 (77)	117.72	125.76	(7)	1.76	1.64	-		
46 (84)	94.92	77.08	(14)	6.08	7.44	-		
47 (91)	36.16	40.40	(21)	21.04	12.84	-		
48 (98)	65.52	90.52	(28)	21.12	10.36	-		
49	-	-	(35)	29.32	26.60	-		
50	-	-	(42)	50.76	53.92	-		
51	-	-	(49)	44.16	47.16	(7)	0.44	0.40
52	-	-	(56)	51.88	50.36	(14)	2.40	1.60
1	-	-	(63)	56.32	46.20	(21)	10.04	10.52
2	-	-	(70)	43.12	49.08	(28)	9.96	9.48
3	-	-	(77)	38.28	42.16	(35)	19.60	18.80
4	-	-	-	-	-	(42)	38.64	42.04
5	-	-	-	-	-	(49)	38.92	42.04
6	-	-	-	-	-	(56)	30.16	39.20
7	-	-	-	-	-	(63)	35.80	34.12
8	-	-	-	-	-	(70)	39.40	43.80
9	-	-	-	-	-	(77)	27.36	39.08
10	-	-	-	-	-	(84)	24.08	23.04

- indicates no crop; values in paranthesis indicate DAT

MEAN NO. OF APHIDS IN EARLY PLANTINGS

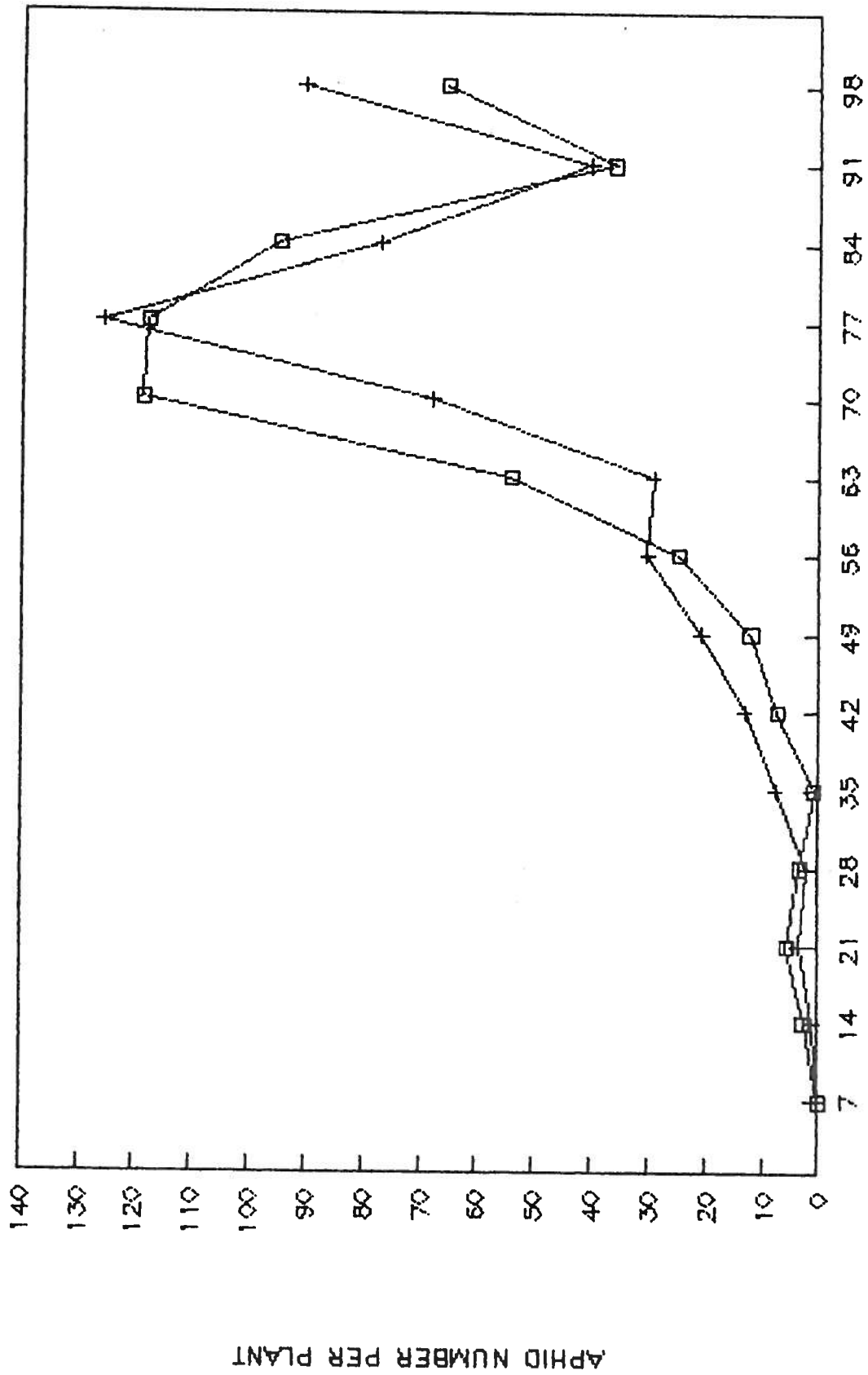


FIG.1(a): DAYS AFTER TRANSPLANTING

□ VAR. GOLDEN ACRE + VAR. PRIDE OF INDIA

c) 77 DAT (45th standard week), whereafter, the population declined and again attained a peak of 90.52 aphids per plant at 98 DAT.

4.1.1.2 Normal planting

In both the varieties, the aphid population was noticed from the transplanting till harvest as shown in Fig. 1b and aphids showed a peak population at 42 DAT with 50.76 and 53.92 aphids per plant on Golden Acre and Pride of India, respectively. The population of the aphid remained very low in normal planting than in early planting.

4.1.1.3 Late planting

In the late planting, the aphid incidence was relatively low, but however, aphids were present through out the crop growth (Table 1 and Fig.1c).

In both the varieties, two peaks of aphid incidence were observed at 49 DAT and 70 DAT (5th and 8th standard week). The aphid population ranged in between 0.44 to 39.40 aphids per plant on Golden Acre and 0.40 to 43.80 aphids per plant on Pride of India.

From the data it is clearly evident that the aphid incidence was more in early plantings.

MEAN NO. OF APHIDS IN NORMAL PLANTINGS

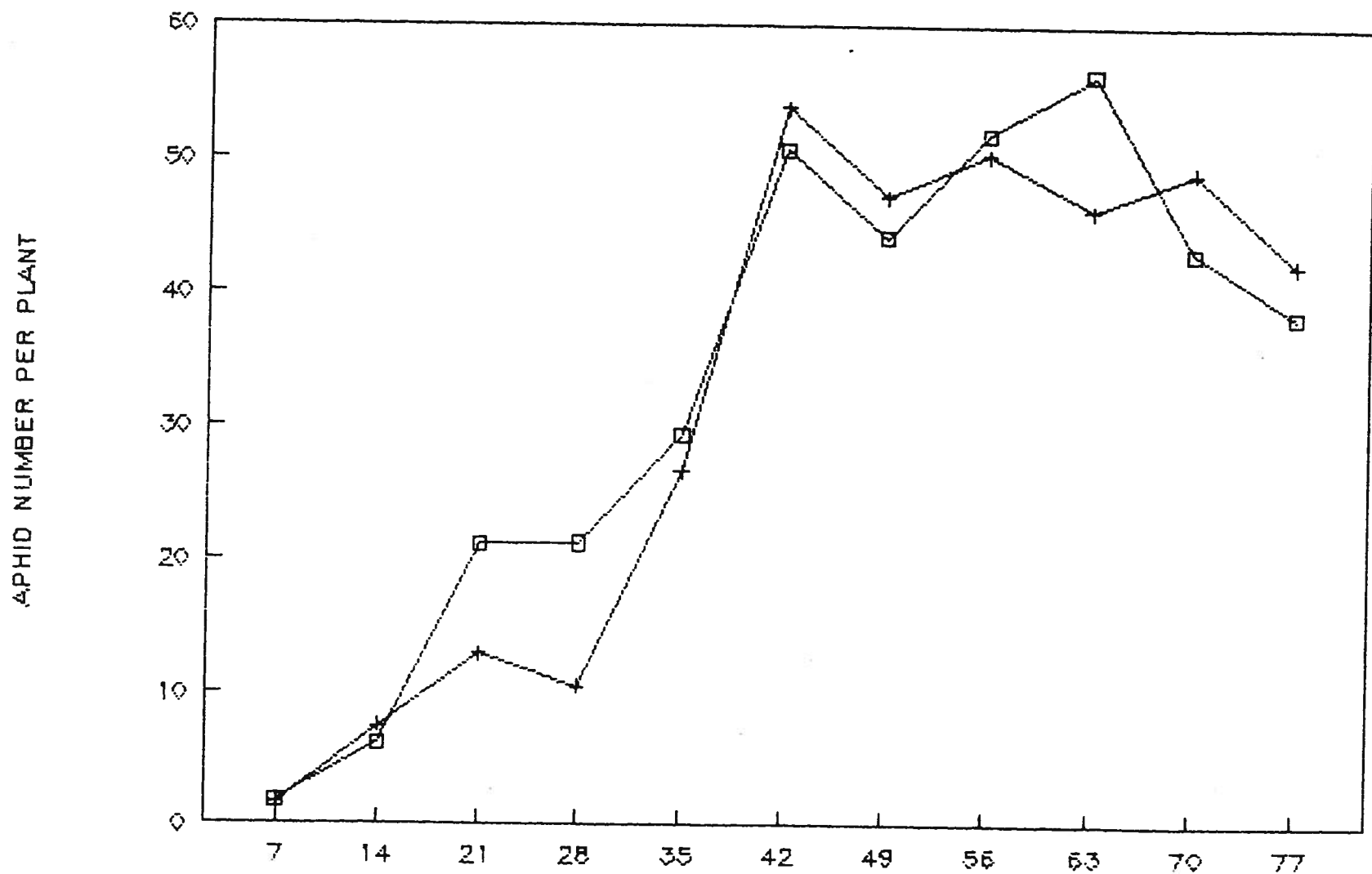


FIG 1 (b) : DAYS AFTER TRANSPLANTING

□ VAR. GOLDEN ACRE + VAR. FRIDE OF INDIA

MEAN NO. OF APHIDS IN LATE PLANTINGS

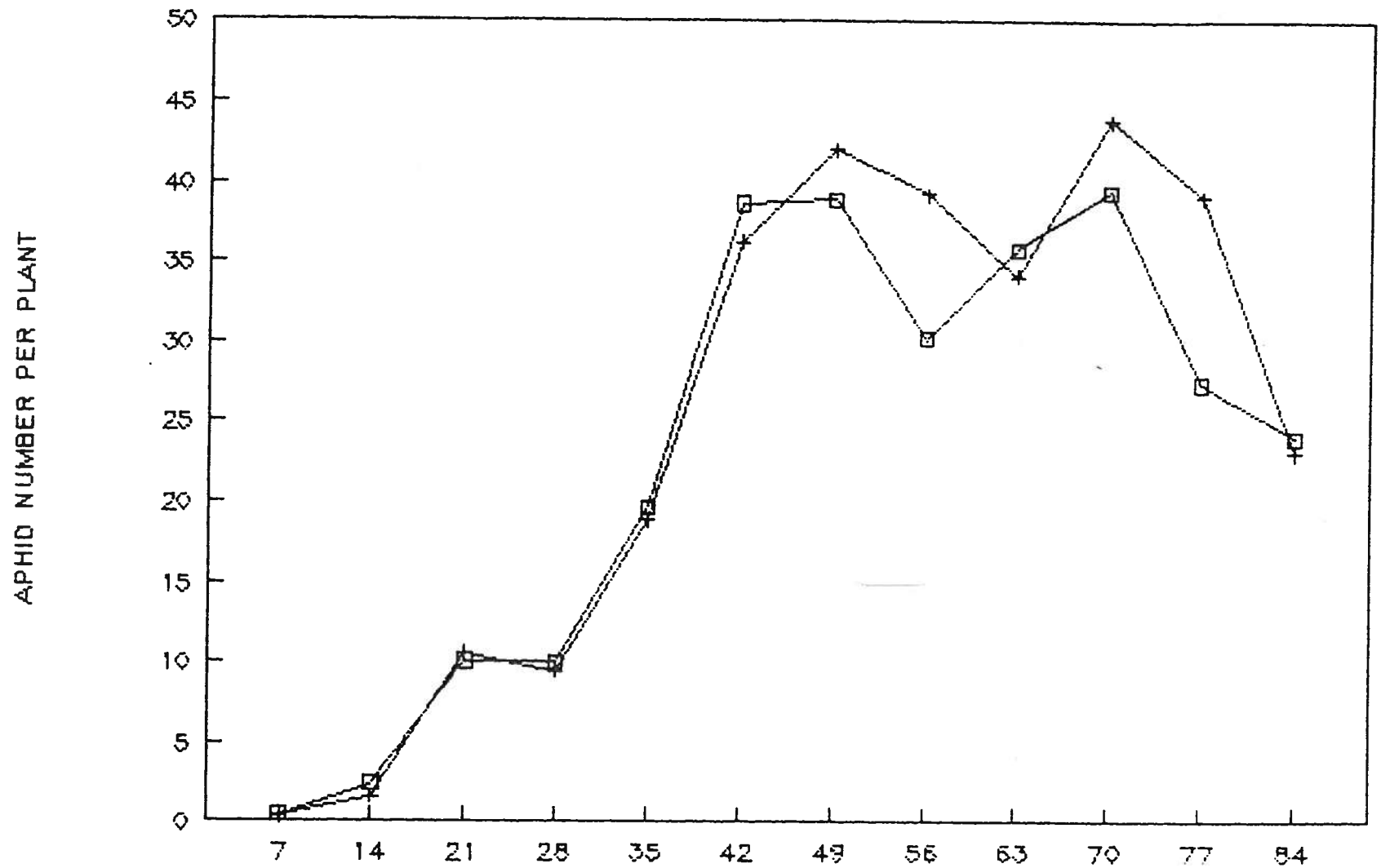


FIG.1 (c) : DAYS AFTER TRANSPLANTING

□ VAR. GOLDEN ACRE + VAR. PRIDE OF INDIA

4.1.2 Diamond-back moth (P. xylostella)

4.1.2.1 Early Planting

In Golden Acre and Pride of India the larvae of DBM were found infesting crop from 14 DAT and showed an increasing trend except at 28 and 49 DAT. Plutella attained a peak at 84 DAT in Golden Acre and afterwards the population showed a declining trend (Table 2). In Pride of India, there were two peaks at 63 DAT and 77 DAT. DBM population was more in Pride of India than Golden Acre and incidence was more in last one month before harvest (Fig.2a).

4.1.2.2 Normal planting

In normal planting, the larvae were present throughout the crop growth. In Golden Acre, the population remained somewhat constant starting from 35 DAT till harvest ranging from 1.28 to 1.44 per plant (Fig. 2b). Whereas, in Pride of India the population attained two peaks at 42 DAT and 70 DAT respectively (1.44 and 1.60 larvae per plant). In this planting, the DBM population was less in Pride of India in comparison to Golden Acre.

4.1.2.3 Late planting

In late planting, the DBM population ranged from 0.10 to 2.64 larvae and 0.04 to 3.20 larvae per plant on Golden Acre and Pride of India, respectively (Table 2).

Table 2: Incidence of diamond back moth (DBM) on two cabbage varieties at different planting dates

Standard week	Early planting		No. of DBM larvae/plant Normal planting		Late planting				
	Golden Acre	Pride of India	Golden Acre	Pride of India	Golden Acre	Pride of India			
35	(7)	0	0	-	-	-	-		
36	(14)	0.08	0.04	-	-	-	-		
37	(21)	0.24	0.76	-	-	-	-		
38	(28)	0	0	-	-	-	-		
39	(35)	0.04	0.04	-	-	-	-		
40	(42)	0.04	0.04	-	-	-	-		
41	(49)	0	0	-	-	-	-		
42	(56)	0.56	0.08	-	-	-	-		
43	(63)	0.36	1.28	-	-	-	-		
44	(70)	0.28	0.36	-	-	-	-		
45	(77)	0.80	1.24	(7)	0.12	0.08	-		
46	(84)	1.28	0.84	(14)	0.48	0.16	-		
47	(91)	0.68	1.08	(21)	0.72	0.48	-		
48	(98)	0.60	0.76	(28)	0.56	0.36	-		
49	-	-	-	(35)	0.04	0.20	-		
50	-	-	-	(42)	1.20	1.44	-		
51	-	-	-	(49)	1.20	0.80	(7)	0.12	0.04
52	-	-	-	(56)	1.20	1.00	(14)	0.24	0.40
1	-	-	-	(63)	1.36	1.36	(21)	0.44	0.72
2	-	-	-	(70)	1.44	1.60	(28)	0.72	1.00
3	-	-	-	(77)	1.20	1.32	(35)	0.64	0.76
4	-	-	-	-	-	-	(42)	0.92	0.64
5	-	-	-	-	-	-	(49)	1.36	1.40
6	-	-	-	-	-	-	(56)	1.32	1.40
7	-	-	-	-	-	-	(63)	1.92	1.60
8	-	-	-	-	-	-	(70)	1.44	1.44
9	-	-	-	-	-	-	(77)	2.64	1.72
10	-	-	-	-	-	-	(84)	2.60	3.20

Values in parenthesis indicate DAT

- indicate no crop

MEAN NO. OF DBM IN EARLY PLANTINGS

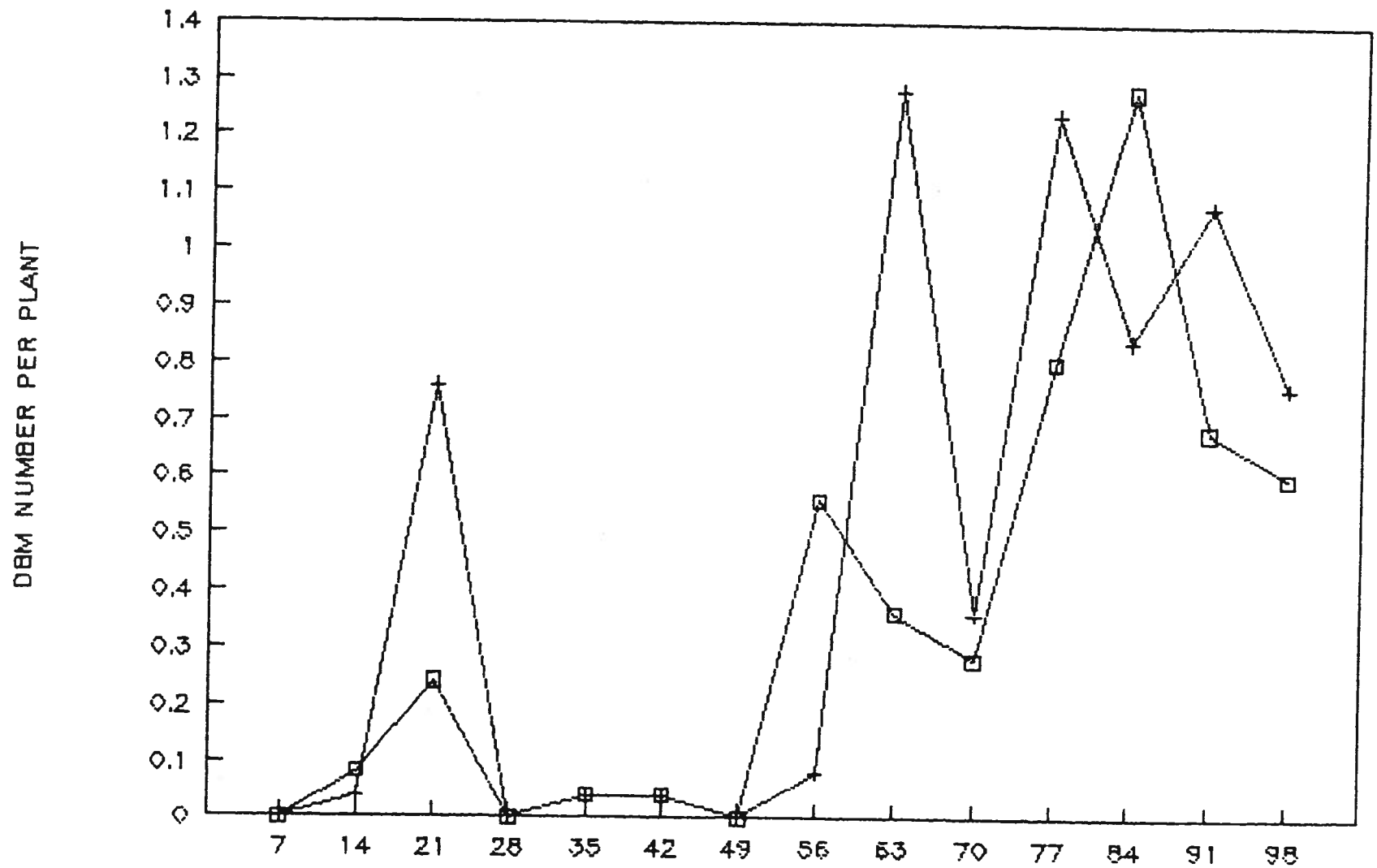


FIG. 2 (a) : DAYS AFTER TRANSPLANTING

□ VAR. GOLDEN ACRE + VAR. PRIDE OF INDIA

MEAN NO. OF DBM IN NORMAL PLANTINGS

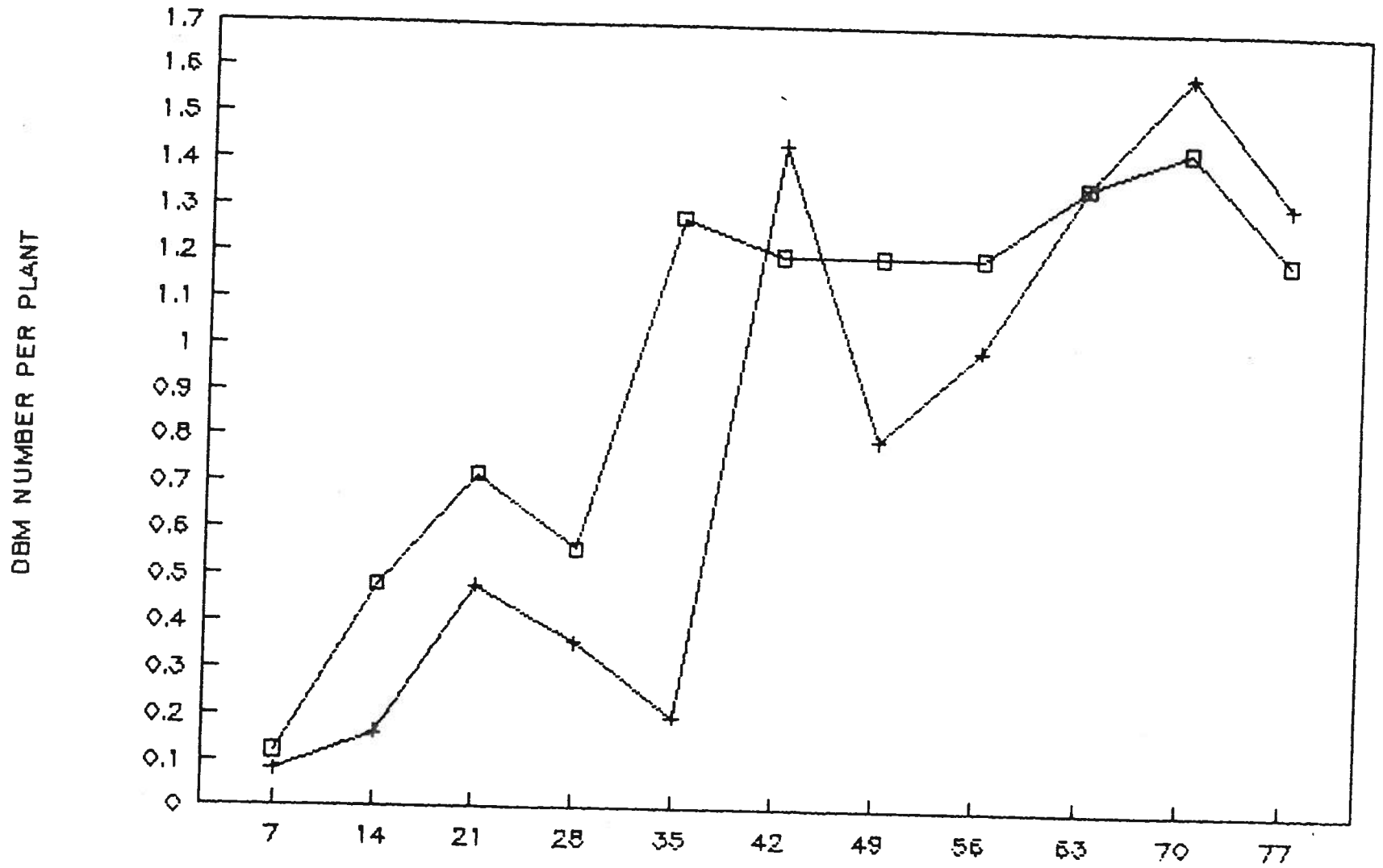


FIG. 2 (b) : DAYS AFTER TRANSPLANTING
□ VAR. GOLDEN ACRE + VAR. PRIDE OF INDIA

It is clearly evident from the Fig. 2c that DBM population was more on the cabbage varieties in the last four weeks before harvest.

4.1.3 Cabbage head borer (H. undalis) and leaf webber (C. binotalis)

Both pests occurred only for one month before harvest during early planting only on both the varieties. The leaf webber population on both varieties ranged in between 1.16 to 1.60 larvae per plant, whereas, Hellula ranged in between 0.80 to 0.92 larvae per plant on Golden Acre and 0.56 to 1.08 larvae per plant in Pride of India (Table 3 and Fig.3&4).

4.2 EFFECT OF ABIOTIC FACTORS ON PEST INCIDENCE

To study the influence of abiotic factors (meteorological parameters) on the population build-up of pest two approaches were used. One approach was by super imposing weekly meteorological data on the incidence of the pests. Secondly, the individual and cumulative effect of four different weather parameters on the population build-up of pests during different stages of crop growth in different plantings were determined through simple, multiple and step down regression analysis.

4.2.1 Superimposing technique

4.2.1.1 Aphid

The aphid appeared in second week in early transplanted crop and first week after transplanting in normal and late plan-

MEAN NO. OF DBM IN LATE PLANTINGS

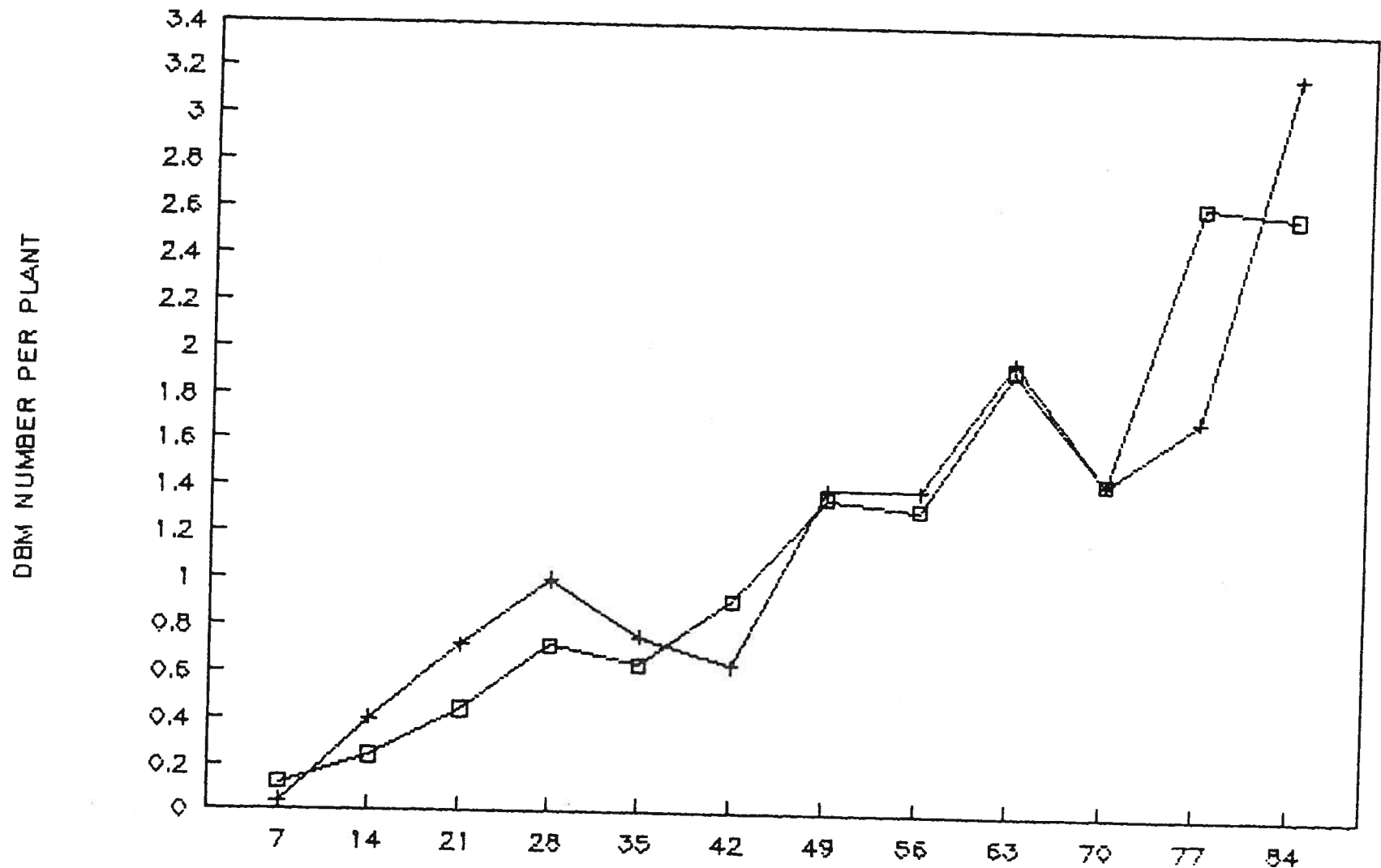


FIG. 2 (c) : DAYS AFTER TRANSPLANTING

□ VAR. GOLDEN ACRE + VAR. PRIDE OF INDIA

Table 3: Incidence of H. undalis and C. binotalis on two cabbage varieties

Standard week	No. of Crocidolomia/plant		No. of Hellula/plant	
	Golden Acre	Pride of India	Golden Acre	Pride of India
45 (77)	1.32	1.36	0.92	1.04
46 (84)	1.60	1.60	0.80	0.56
47 (91)	1.56	1.56	0.84	1.08
48 (98)	1.16	1.16	0.84	1.04

Values in parenthesis indicate DAT

MEAN NO. OF HELLUOLA IN EARLY PLANTINGS

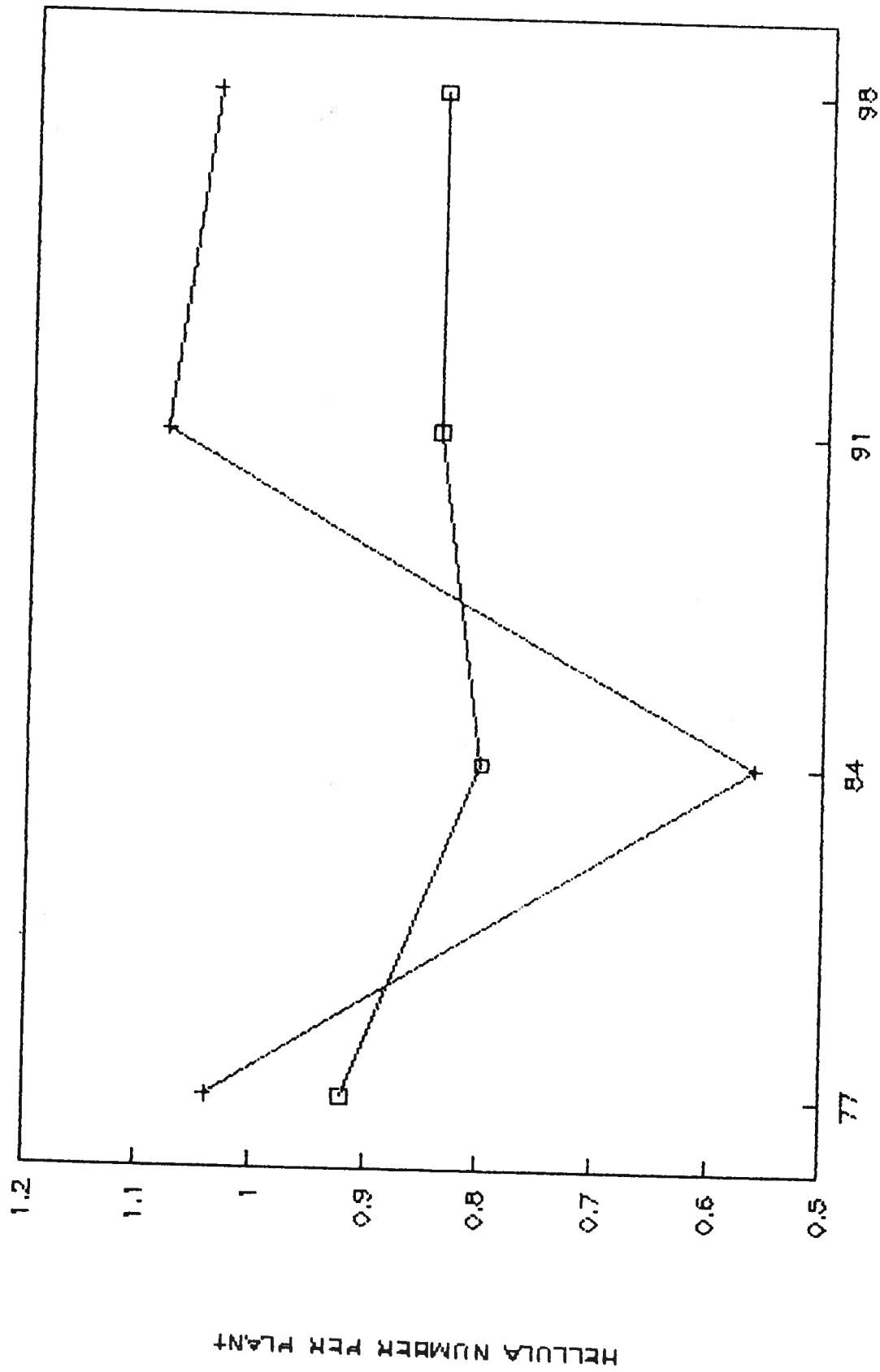


FIG. 3 : DAYS AFTER TRANSPLANTING
□ VAR. GOLDEN ACRE + VAR. PRIDE OF INDIA

MEAN NO. OF CROCIDOLOMIA

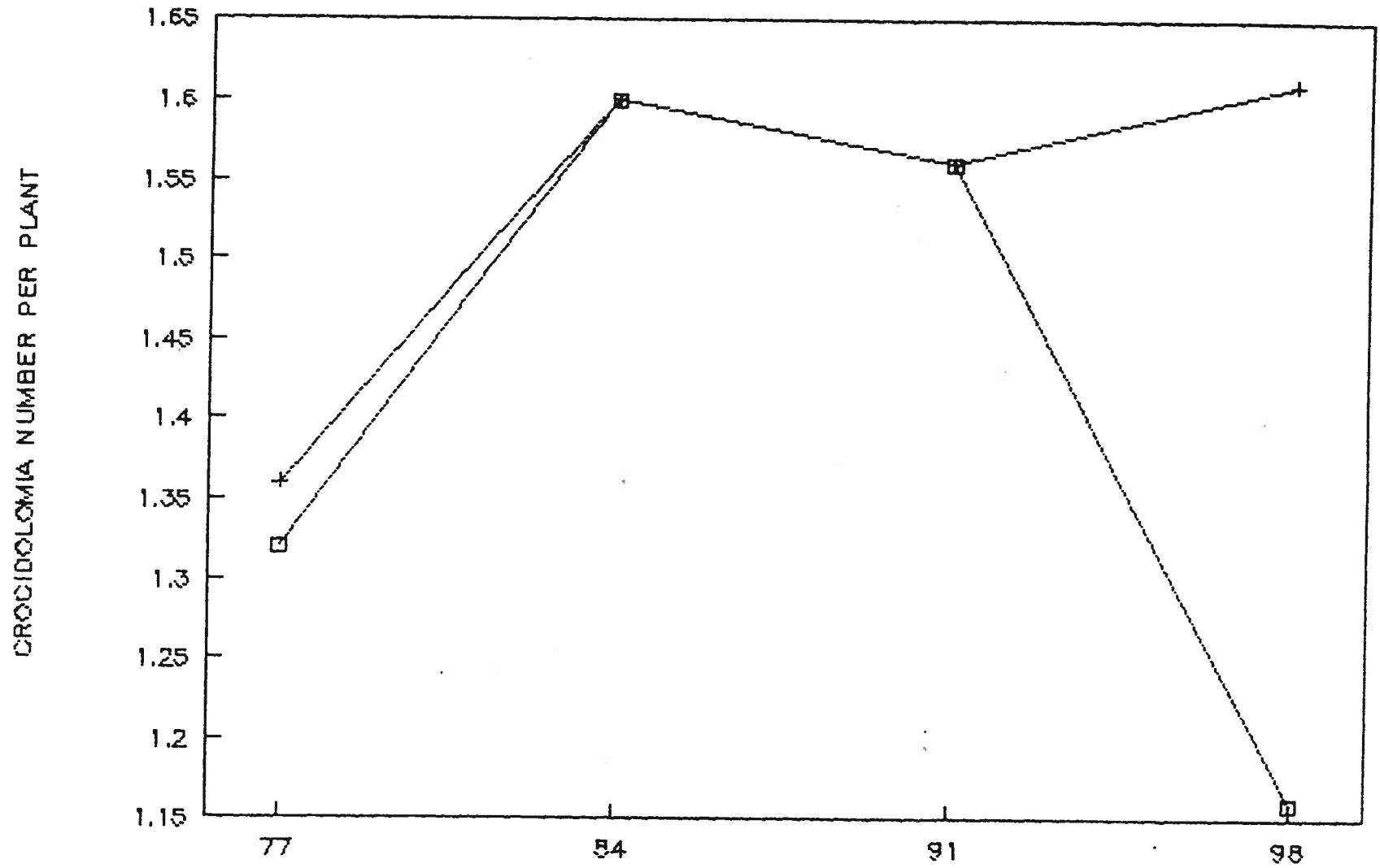


FIG. 4 : DAYS AFTER TRANSPLANTING

□ VAR. GOLDEN ACRE + VAR. PRIDE OF INDIA

ted crops, respectively and its population continued to build-up throughout the vegetative stage. The maximum temperature in early planting ranged from 27.1°C to 32.2°C and it is seen that with increase in temperature the population of aphids also increased. The RH also played a positive role in the build-up of the pest and the RH ranged from 67 to 87 per cent. The population declined with a heavy downpour of 155.4 mm (38th standard week) (Fig. 5).

In normal planted crop, the population increased with an increase in maximum temperature (26.9°C to 29.5°C). RH did not play a major role in the population build-up (Fig. 5).

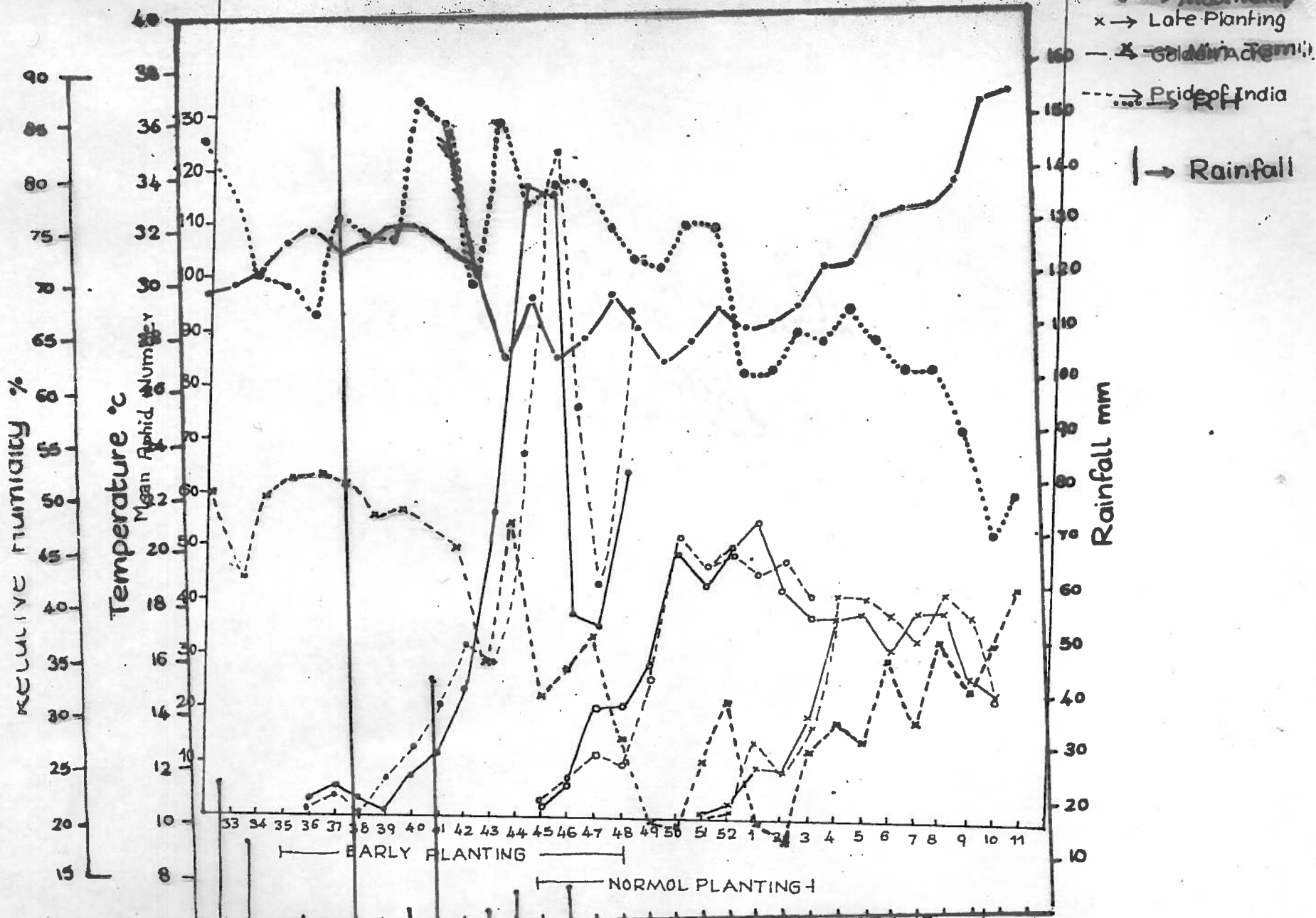
In the late planting, the population increased with an increase in temperature (27.6°C to 36.6°C). Other weather parameters did not play a major role in the population build-up of the pest (Fig. 5).

4.2.1.2 DBM

The DBM population incidence started from second week after transplanting in early planted crop and there was no population recorded on 28 and 49 DAT (38 and 41 standard week), when there was a heavy rainfall of 155.4 mm and 46 mm respectively (Table 2 and Appendix I), with a decrease in temperature the population increased in the early planting (Fig. 6).

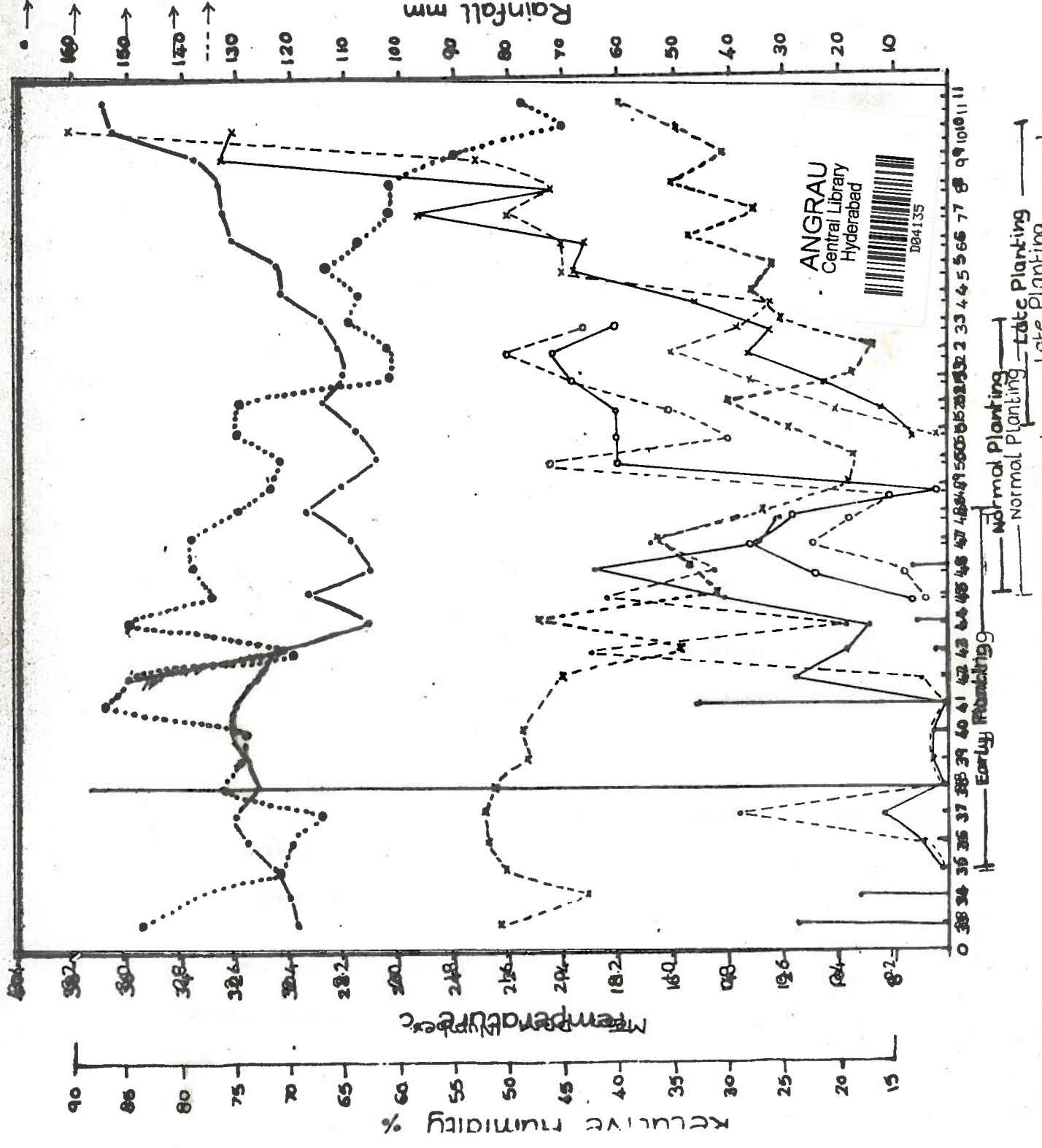
In the normal planted crop the population build-up was influenced with the decrease in temperatures. Other factors did not play a major role in population build-up (Fig. 6).

Meteorological Data of During Crop Season. Rajendranagar (A.R.I. A.P.A.U)



Metecological Data of During Crop Season: Rajendranagar (A.P.A.U)

• → **APR. TEMP**
 • → **Early Planting**
 • → **Normal Planting**
 • → **Late Planting**
 • → **Golden Rainfall**
 • → **Pride of India**



In the late plantings the population build-up was influenced with the increase in temperature and decrease in RH as the season prolonged (Fig. 6).

4.2.1.3 Hellula

The incidence of Hellula was seen in the last month before harvesting in the early planting and the pest was not recorded in the normal and late plantings in both the varieties. The population build-up was favoured by decrease in temperatures and RH during its infestation. A rainfall of 7 mm in second week of infestation (46th standard week) had a negative impact on its build-up (Fig. 7 and Table 3).

4.2.1.4 Crocidolomia

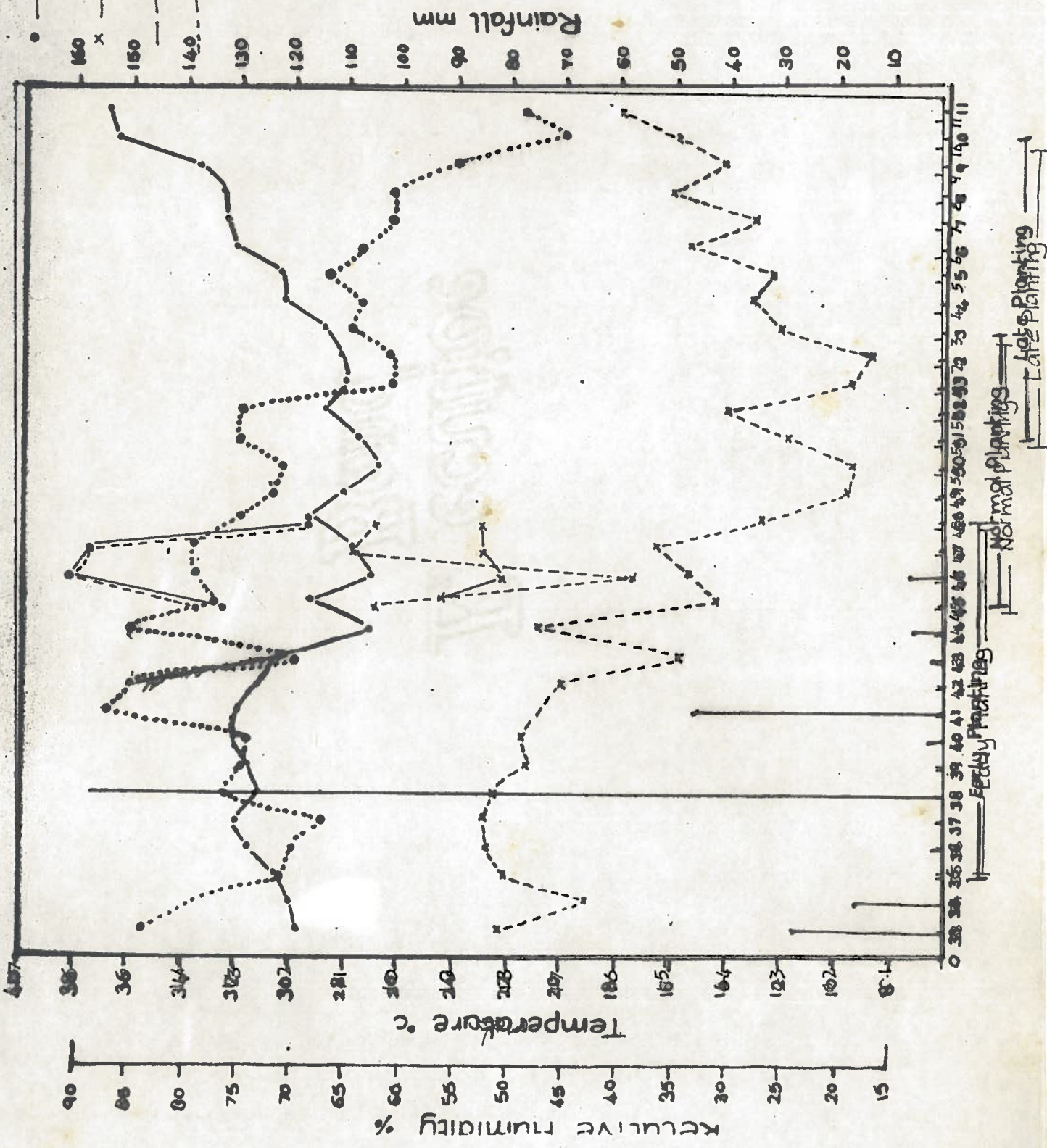
The pest incidence was seen in the last week before harvest on both varieties in early plantings. Incidence was not recorded in the normal and late planted crop. Minimum temperature and RH had a favourable impact on the population build-up. The rainfall in 46th standard week resulted in a decrease of the population (Table 3 and Fig. 7).

4.2.2 Correlations and regression between climatological parameters and pest population

4.2.2.1 Temperature vs. aphid incidence

Maximum temperature exerted a negative influence on the incidence of the cabbage aphid in the early and normal sown crop with a high significant correlation in early planting in the two

• → **Max Temp**
 x → **Min. Temp**
 x → **Hellula**
 ... → **RH**
 — → **Golden Acre**
 - - - → **Pink Rosefolia**



varieties and a non significant relationship in the normal planted crop. In the late planted crop, the temperature exerted a positive influence on the incidence of the pest i.e. in both the varieties as the temperature increased the pest incidence also increased. The mean maximum temperature ranged in between 27.1°C to 32.2°C, 26.9°C to 29.5°C, and 27.6°C to 36.6°C in early, normal and late plantings respectively (Appendix I). The correlation between maximum temperature and aphid incidence in Golden Acre indicates a significant linear relationship in the early plantings and non significant linear relationship in normal and late plantings. Whereas, in Pride of India, in the early and late plantings correlations were significant at 0.01 probability and had a non significant relationship in normal planted crop (Table 4).

Minimum temperature exerted a negative influence on the incidence of the aphid in the early and normal planted crop, whereas, in the late planted crop minimum temperature exerted a positive influence on the incidence of the aphids in both the varieties. The correlation between minimum temperature and aphid population showed a significant relationship in early and normal planted crop at 0.05 probability in both the varieties and a exerted a non-significant relationship in the late planted crop (Table 4).

Minimum temperature ranged between 12.8°C and 29.7°C in the early planted crop, 8.8°C and 16.7°C in the normal planting and 8.8°C and 16.1°C in the late planted crop.

Table 4: Correlation and regression between weather parameters with cabbage aphid incidence on two cabbage varieties at different dates of planting

Independent variable variable (x)	GOLDEN ACRE		PRIDE OF INDIA	
	Regression equation $Y = a + bx$	Correlation coefficient(r)	Regression equation $Y = a + bx$	Correlation coefficient(r)
Early Plantings				
(a) Maximum temperature	$Y = 13656.38 - 423.3834x^{**}$	-0.9031	$Y = 11769.7200 - 362.4739x^{**}$	-0.8770
(b) Minimum Temperature	$Y = 4086.2240 - 155.9145x^*$	-0.6178	$Y = 4036.5720 - 156.5771x^{**}$	-0.7038
(c) Relative Humidity	$Y = -4064.0200 + 66.0462x$	+0.3603	$Y = -3261.3530 + 54.7109x$	+0.3385
(d) Rainfall	$Y = 1084.3800 - 6.6476x$	-0.2486	$Y = 1016.1490 - 6.3079x$	-0.2675
Normal Plantings				
(a) Maximum temperature	$Y = 3663.1820 - 100.1802x$	-0.1875	$Y = 5448.567 - 164.7932x$	-0.2820
(b) Minimum Temperature	$Y = 2215.2050 - 112.4132x^*$	-0.6494	$Y = 2351.920 - 126.7612x^*$	-0.6695
(c) Relative Humidity	$Y = 4033.6980 - 44.5591x^*$	-0.6414	$Y = 4297.714 - 48.7872x^*$	-0.6421
(d) Rainfall	$Y = 901.7000 - 104.1250x$	-0.4896	$Y = 854.700 - 92.8750x$	-0.3993
Late Plantings				
(a) Maximum temperature	$Y = -1830.5820 + 78.1690x$	+0.5723	$Y = -197.9160 + 7.832x^{**}$	+0.9333
(b) Minimum Temperature	$Y = -416.0031 + 76.2487x$	+0.4790	$Y = -37.3832 + 5.1439x$	+0.5579
(c) Relative Humidity	$Y = 1697.0060 - 18.1173x$	-0.4444	$Y = 157.0941 - 2.0657x^{**}$	-0.8749
(d) Rainfall	-	-	-	-

Y = Cabbage aphid population

* = Significant at P = 0.05

** = Significant at P = 0.01

- = No correlations as there was no rainfall

ADRIAN INTRAL 55
D 4135
20.4.93

4.2.2.2 Relative humidity vs. aphid incidence

The aphid incidence in general was negatively correlated with relative humidity in the normal and late planted crop in both the varieties but showed a positive influence in the early planted crop. There was a high significant correlation in the late planted crop in Pride of India variety at 0.01 probability. The relative humidity ranged in between 67 and 87 per cent 61 and 79 per cent and 45 and 75 per cent in early, normal and late planted crop respectively (Table 4).

4.2.2.3 Rainfall vs. aphid incidence

The rainfall in general exerted negative influence on the cabbage aphid incidence in the early and normal planted crop in both the varieties. The correlation between rainfall and the pest incidence indicated a non significant linear relationship. The late planted crop did not experience any rainfall (Table 4).

4.2.2.4 Temperature vs. DBM incidence

Maximum temperature exerted a negative influence on the DBM population in the early and normal planted crop in both the varieties. The correlation between maximum temperature and DBM in Golden Acre indicated a highly significant linear relationship at 0.01 probability, whereas, in Pride of India the significance was obtained at 0.05 probability. In the late planted crop maximum temperature exerted a positive influence on the DBM population in both the varieties (Table 5) indicating an increase in pest population with increase in maximum temperature.

Table 5: Correlation and regression between weather parameters with DBM incidence on two cabbage varieties at different dates of planting

Independent variable variable (x)	GOLDEN ACRE		PRIDE OF INDIA	
	Regression equation $Y = a + bx$	Correlation coefficient(r)	Regression equation $Y = a + bx$	Correlation coefficient(r)
Early Plantings				
(a) Maximum temperature	$Y = 99.8486 - 3.0317x^{**}$	-0.7357	$Y = 109.1746 - 3.2501x^*$	-0.6350
(b) Minimum Temperature	$Y = 42.1189 - 1.6583x^{**}$	-0.7476	$Y = 42.8438 - 1.5549x^*$	-0.5640
(c) Relative Humidity	$Y = -19.2393 + 0.3708x$	+0.2301	$Y = -14.1139 + 0.3401x$	+0.1699
(d) Rainfall	$Y = 10.2573 - 0.0748x$	-0.3184	$Y = 12.8732 - 0.0641x$	-0.2196
Normal Plantings				
(a) Maximum temperature	$Y = 126.6870 - 3.6194x$	-0.2891	$Y = 103.2166 - 2.9462x$	-0.1784
(b) Minimum Temperature	$Y = 61.3216 - 2.9995x^{**}$	-0.7394	$Y = 61.2294 - 3.3545x^*$	-0.6270
(c) Relative Humidity	$Y = 108.0552 - 1.1641x^*$	-0.7150	$Y = 143.1021 - 1.7141x^{**}$	-0.7983
(d) Rainfall	$Y = 25.7000 - 1.9028x$	-0.818	$Y = 21.6000 - 2.444x$	-0.3719
Late Plantings				
(a) Maximum temperature	$Y = -2235.7660 + 92.6146x$	+0.6135	$Y = -191.5008 + 7.1969$	+0.9211
(b) Minimum Temperature	$Y = -616.5911 + 94.6821x$	+0.5381	$Y = -29.7964 + 4.6150$	+0.5068
(c) Relative Humidity	$Y = 2159.8990 - 24.9767x$	-0.5544	$Y = 145.2074 - 1.8618$	-0.7985
(d) Rainfall	-	-	-	-

Y = DBM population

* = Significant at P = 0.05

** = Significant at P = 0.01

- = No correlation as there was no rainfall

The DBM population in the early and normal planted crop was negatively correlated with minimum temperature but showed a positive influence in the late planted crop in both Golden Acre and Pride of India. The correlations between minimum temperature and DBM showed a high significance in the early and normal planted crop at 0.01 probability in Golden Acre and showed a significant linear relationship at 0.05 probability in Pride of India. The correlation was found to be non-significant in the late planted crop in both the varieties (Table 5).

4.2.2.5 Relative Humidity vs. DBM incidence

Relative humidity exerted a positive influence on the DBM population in early planted crop. Whereas, in the normal and late planted crop relative humidity exerted a negative influence. Correlation between RH and DBM showed a non-significant relationship in both the varieties in the early and late plantings, whereas in normal planting the correlation was found to be significant at 0.05 probability in Golden Acre and 0.01 probability in Pride of India (Table 5).

4.2.2.6 Rainfall vs. DBM incidence

Rainfall in general exerted a negative influence on the DBM incidence in the early and normal plantings in both the varieties. The late planting did not receive any rainfall, hence regressions were not carried out (Table 5).

4.2.2.7 Temperature vs. Hellula

Maximum temperature exerted a negative influence on the cabbage head borer population. The correlation between maximum temperature and Hellula was found to be highly significant at 0.01 probability in both the varieties (Table 6).

Minimum temperature exerted a negative influence on Hellula population. The correlation between minimum temperature and Hellula was found to be highly significant at 0.01 probability in both the varieties in the early planted crop only, as Hellula incidence was recorded in this season alone (Table 6).

4.2.2.8 Relative Humidity vs. Hellula

Relative humidity exerted a positive influence on the population build-up of Hellula i.e., with increase in RH the pest population also increased. The correlation between RH and the pest incidence exerted a non significant linear relationship (Table 6).

4.2.2.9 Rainfall vs. Hellula

Rainfall exerted a negative influence on the incidence of Hellula in both the varieties. A non significant linear relationship was found between rainfall and Hellula (Table 6).

4.2.2.10 Maximum Temperature vs. Crocidolomia

Maximum temperature exerted a negative influence on the pest population build-up in early planted crop. A high signifi-

Table 6: Correlation and regression between weather parameters with cabbage head borer and cabbage leaf webber on two cabbage varieties

Independent variable variable (x)	GOLDEN ACRE		PRIDE OF INDIA	
	Regression Equation $Y = a + bx$	Correlation coefficient(r)	Regression Equation $Y = a + bx$	Correlation coefficient(r)
<u>Hellula</u>				
(a) Maximum temperature	$Y = 102.2111 - 3.2060x^*$	-0.7757	$Y = 100.3384 - 3.1387x^*$	-0.6861
(b) Minimum Temperature	$Y = 40.0103 - 1.6959x^*$	-0.7623	$Y = 41.7932 - 1.7782x^*$	-0.7220
(c) Relative Humidity	$Y = -8.9765 + 0.1989x$	+0.1231	$Y = -6.6844 + 0.1708x$	+0.0955
(d) Rainfall	$Y = 7.0629 - 0.0539x$	-0.2272	$Y = 7.2732 - 0.0578x$	-0.2215
<u>Crocidolomia</u>				
(a) Maximum temperature	$Y = 148.4254 - 4.6826x^*$	-0.8009	$Y = 36.1123 - 1.1082x^*$	-0.6922
(b) Minimum Temperature	$Y = 50.9867 - 2.1463x^*$	-0.6820	$Y = 13.6546 - 0.5382x^{**}$	-0.6246
(c) Relative Humidity	$Y = -18.4172 + 0.3488x$	+0.1526	$Y = -7.1576 + 0.1321x$	+0.2110
(d) Rainfall	$Y = 9.3157 - 0.0695x$	-0.2085	$Y = 3.2904 - 0.0228x$	-0.2500

$Y =$ Hellula and Crocidolomia population

* = Significant at $P = 0.05$

** = Significant at $P = 0.01$

cant linear correlation was observed at 0.01 probability in both the varieties (Table 6).

A negative influence on the pest population build up was seen between minimum temperature and Crocidolomia in both the varieties. A high significant linear relationship was seen at 0.01 probability in variety Golden Acre whereas, it was significant at 0.05 probability in variety Pride of India (Table 6).

4.2.2.11 Relative Humidity vs. Crocidolomia

As seen from the Table 6, relative humidity exerted a positive influence on the population build-up of Crocidolomia. The correlation between RH and pest incidence exerted a non significant linear relationship.

4.2.2.12 Rainfall vs. Crocidolomia

A negative non-significant relationship was noticed between rainfall and Crocidolomia incidence in early planting (Table 6).

4.2.3 Overall correlations between climatological parameters and pest populations

Multiple regression equations were fitted to study the relationship between pest incidence and various other parameters and the results are presented in Tables 7 to 9.

4.2.3.1. Aphid

In the early planted crop, only RH had a positive influence on the aphid population build-up, whereas, others had a negative influence in both varieties. The correlation between maximum temperature and aphid incidence was found to be highly significant at 0.01 probability in variety Golden Acre and at 0.05 probability in variety Pride of India. All other parameters contributed negatively in combination (Table 7).

In normal planted crop, minimum temperature exerted a positive influence on the aphid population. In variety Pride of India, all factors in combination had a negative correlation with the aphid population and none of these factors were found to be significant.

In the late planted crop, among all the weather parameters in combination maximum and minimum temperatures had a positive influence on the aphid population build-up in Golden Acre but none of these factors were found to be significant. In case of Pride of India, minimum temperature alone had a positive influence on the aphid population and none of these factors were found significant.

4.2.3.2 DBM

In the early planted crop, RH alone had a positive influence on the DBM population build-up among all the weather parameters in combination in both the varieties. Minimum tempe-

Table 7: Multiple linear regression interaction of cabbage aphid incidence on two cabbage varieties and weather parameters

X1 = Maximum temperature

X2 = Minimum temperature

X3 = Relative humidity

X4 = Rainfall

Y = Aphid incidence

Var. Golden Acre

$$\text{Early plantings } Y = 9382.4030 - \overset{**}{347.6636} X1 - \overset{NS}{36.4373} X2 + \overset{NS}{36.1567} X3 - \overset{NS}{1.7656} X4$$

(94.4439) (50.6823) (28.4683) (3.7344)

(R2 = 0.7782)

$$\text{Normal plantings } Y = 10002.49 - \overset{NS}{236.0931} X1 + \overset{NS}{2.4574} X2 - \overset{NS}{34.2423} X3 - \overset{NS}{109.0371} X4$$

(161.2615) (81.6104) (29.8697) (68.0194)

(R2 = 0.6408)

$$\text{Late plantings } Y = -1042.1170 + \overset{NS}{49.9613} X1 + \overset{NS}{26.2558} X2 - \overset{NS}{4.2480} X3$$

(122.7785) (95.8983) (25.2623)

(R2 = 0.3346)

Var. Pride of India

$$\text{Early plantings } Y = 6150.742 - \overset{*}{228.4418} X1 - \overset{NS}{81.8640} X2 + \overset{NS}{42.6850} X3 - \overset{NS}{1.4013} X4$$

(85.5829) (44.3175) (24.8930)

(R2 = 0.7818)

$$\text{Normal plantings } Y = 11680.13 - \overset{NS}{286.099} X1 - \overset{NS}{6.9932} X2 - \overset{NS}{36.9600} X3 - \overset{NS}{99.0673} X4$$

(181.8206) (88.7141) (32.4697) (73.9401)

(R2 = 0.6451)

$$\text{Late plantings } Y = 1442.5710 - \overset{NS}{17.1222} X1 + \overset{NS}{80.7379} X2 - \overset{NS}{21.9008} X3$$

(123.7339) (96.6445) (25.4589)

(R2 = 0.4468)

* : Significant at 0.01; ** : Significant at 0.05 ; NS : Non significant

perature showed a significant influence at 0.05 probability in Golden Acre but none of the weather factors were found significant in Pride of India (Table 8).

In the normal planted crop, all weather parameters in combination had a negative non significant influence on DBM population in both the varieties.

Maximum temperature alone had influenced the population build-up in combination in Golden Acre whereas, maximum temperature and relative humidity had a positive influence on the DBM build up in Pride of India in late planted crop.

4.2.3.3 Hellula

Relative humidity exerted a positive influence on the Hellula build-up when all the weather parameters were regressed in both the varieties. None of the weather parameters were found to be significant (Table 9).

4.2.3.4 Crocidolomia

Relative humidity had exerted a positive influence on the pest population build-up in combination with all weather parameters in both the varieties (Table 9). None of the weather parameters were found to have a significant relationship.

4.2.4 Step down regression

Step down regressions were worked out to have a clear understanding of the weather factors, which have directly contri-

Table 8: Multiple linear regression interaction of DBM incidence on two cabbage varieties and weather parameters

X1 = Maximum temperature

X2 = Minimum temperature

X3 = Relative humidity

X4 = Rainfall

Y = DBM incidence

Var. Golden Acre

$$\text{Early plantings } Y = 30.6801 - \begin{matrix} \text{NS} \\ 0.9917 \text{ X1} \\ (1.1049) \end{matrix} - \begin{matrix} * \\ 1.3444 \text{ X2} \\ (0.5929) \end{matrix} + \begin{matrix} \text{NS} \\ 0.4617 \text{ X3} \\ (0.3330) \end{matrix} - \begin{matrix} \text{NS} \\ 0.0236 \text{ X4} \\ (0.0432) \end{matrix}$$

(R2 = 0.7280)

$$\text{Normal plantings } Y = 252.9474 - \begin{matrix} \text{NS} \\ 5.6775 \text{ X1} \\ (3.4468) \end{matrix} - \begin{matrix} \text{NS} \\ 0.4489 \text{ X2} \\ (1.6817) \end{matrix} - \begin{matrix} \text{NS} \\ 0.8559 \text{ X3} \\ (0.6155) \end{matrix} - \begin{matrix} \text{NS} \\ 1.7440 \text{ X4} \\ (1.4017) \end{matrix}$$

(R2 = 0.7223)

$$\text{Late plantings } Y = -132.4253 + \begin{matrix} * \\ 7.2501 \text{ X1} \\ (2.1234) \end{matrix} - \begin{matrix} \text{NS} \\ 2.0402 \text{ X2} \\ (1.6585) \end{matrix} - \begin{matrix} \text{NS} \\ 0.5635 \text{ X3} \\ (0.4364) \end{matrix}$$

(R2 = 0.9406)

Var. Pride of India

$$\text{Early plantings } Y = 67.2391 - \begin{matrix} \text{NS} \\ 1.9252 \text{ X1} \\ (1.9420) \end{matrix} - \begin{matrix} \text{NS} \\ 0.8979 \text{ X2} \\ (1.0422) \end{matrix} + \begin{matrix} \text{NS} \\ 0.2668 \text{ X3} \\ (0.5854) \end{matrix} - \begin{matrix} \text{NS} \\ 0.0133 \text{ X4} \\ (0.0768) \end{matrix}$$

(R2 = 0.2133)

$$\text{Normal plantings } Y = 252.9474 - \begin{matrix} \text{NS} \\ 5.6775 \text{ X1} \\ (3.4468) \end{matrix} - \begin{matrix} \text{NS} \\ 0.4489 \text{ X2} \\ (1.6817) \end{matrix} - \begin{matrix} \text{NS} \\ 0.8559 \text{ X3} \\ (0.6155) \end{matrix} - \begin{matrix} \text{NS} \\ -1.7440 \text{ X4} \\ (1.4017) \end{matrix}$$

(R2 = 0.7223)

$$\text{Late plantings } Y = -270.5052 + \begin{matrix} ** \\ 11.2329 \text{ X1} \\ (2.0551) \end{matrix} - \begin{matrix} * \\ 4.9412 \text{ X2} \\ (1.6051) \end{matrix} + \begin{matrix} \text{NS} \\ 0.3104 \text{ X3} \\ (0.4228) \end{matrix}$$

(R2 = 0.9430)

* : Significant at 0.01; ** : Significant at 0.05 ; NS : Non significant

Table 9: Multiple linear regression interaction of cabbage head borer and cabbage leaf webber incidence on two cabbage varieties and weather parameters

X1 = Maximum temperature

X2 = Minimum temperature

X3 = Relative humidity

X4 = Rainfall

Y = Hellula incidence

Var. Golden Acre

$$\text{Early plantings } Y = 68.6115 - \begin{matrix} \text{NS} \\ 1.7297 X1 \\ (1.1185) \end{matrix} - \begin{matrix} \text{NS} \\ 1.1437 X2 \\ (0.6002) \end{matrix} + \begin{matrix} \text{NS} \\ 0.1584 X3 \\ (0.3372) \end{matrix} + \begin{matrix} \text{NS} \\ 0.0060 X4 \\ (0.0440) \end{matrix}$$

(R2 = 0.5997)

Var. Pride of India

$$\text{Early plantings } Y = 59.4076 - \begin{matrix} \text{NS} \\ 1.3724 X1 \\ (1.4688) \end{matrix} - \begin{matrix} \text{NS} \\ 1.3551 X2 \\ (0.7882) \end{matrix} - \begin{matrix} \text{NS} \\ 0.1962 X3 \\ (0.4427) \end{matrix} + \begin{matrix} \text{NS} \\ 0.0041 X4 \\ (0.0581) \end{matrix}$$

(R2 = 0.6100)

Y = Crocidolomia incidence

Var. Golden acre

$$\text{Early plantings } Y = 122.3692 - \begin{matrix} \text{NS} \\ 3.4401 X1 \\ (1.6816) \end{matrix} - \begin{matrix} \text{NS} \\ 0.9807 X2 \\ (0.9024) \end{matrix} + \begin{matrix} \text{NS} \\ 0.1086 X3 \\ (0.5069) \end{matrix} + \begin{matrix} \text{NS} \\ 0.0064 X4 \\ (0.0665) \end{matrix}$$

(R2 = 0.6870)

Var. Pride of India

$$\text{Early plantings } Y = 252.9474 - \begin{matrix} \text{NS} \\ 5.6775 X1 \\ (3.4468) \end{matrix} - \begin{matrix} \text{NS} \\ 0.4489 X2 \\ (1.6817) \end{matrix} - \begin{matrix} \text{NS} \\ 0.8559 X3 \\ (0.6155) \end{matrix} - \begin{matrix} \text{NS} \\ 1.7440 X4 \\ (1.4017) \end{matrix}$$

(R2 = 0.7223)

* : Significant at 0.01; ** : Significant at 0.05 ; NS : Non significant

buted to incidence of the pests either individually or in concert. In the Table 10a and 10b, the weather parameters which have contributed for the incidence of pests and the corresponding t-table values have been indicated.

4.2.4.1 Aphid

The results of the step down regression in early planted crop indicated that rainfall, minimum temperature and relative humidity did not have any significant impact on the incidence of the aphid. Therefore, they were eliminated in that order. However, at the third step the maximum temperature had a significant influence on the aphid incidence over relative humidity as indicated by higher t-table value of 7.2862 as compared to 0.9996 for relative humidity (Table 10a). Therefore, the latter was eliminated at the final stage in case of variety Golden Acre. In case of Pride of India, rainfall and relative humidity did not have any significant impact on the aphid incidence. In the third stage, it was observed that maximum temperature had a significant influence, when compared to minimum temperature with a t-table value of 6.3223 (Table 10b).

In the normal planted crop, when the data was subjected to step down regression initially minimum temperature, maximum temperature and rainfall were eliminated as they did not have a significant influence on aphid infestation. In the final step, relative humidity was found to have a significant influence on aphid incidence which was indicated by a higher t-table value of

Table 10a Step down Regression analysis of different pests of cabbage on variety Golden Acre planted at different dates

Pests	Early Planting	Normal Planting	Late Planting
Aphids	Y = 13656.38 - 423.38 Max. Temp. R ² = 0.8156 [7.2862**]	Y = 4033.69 - 44.55 RH R ₂ = 0.4113 [2.5081*]	Y = -1830.58+78.16 Max. Temp R ₂ = 0.3275 [2.2069 NS]
DBM	Y = 42.118-1.65 Min. Temp R ² = 0.5589 [3.8994**]	Y = 108.050 - 1.16 RH R ² = 0.5111 [3.0677*]	Y = -71.19 + 5.05 Max. Temp. R ² = 0.9278 [4.5001**] -71.19 - 0.89 RH R ² = 0.9278 [2.6625*]
Hellula	Y = 102.21 - 3.20 Max. Temp. R ² = 0.6017 [4.2584**]		
Crocidolomia	Y = 148.42 - 4.68 Max. Temp. R ² = 0.6414 [4.6337**]		

* = Significant at 0.01; ** = Significant at 0.05; NS = Non significant

Note : The last run equation in the step down regression analysis is given in the table. Value in Paranthesis indicate T-values

Table 10 b : Step down Regression Analysis of different pests of cabbage on variety Pride of India Planted at different dates

Pest	Early Planting	Normal Planting	Late Planting
Aphids	Y = 11769.72 - 362.47 Max. Temp. R ² = 0.7691 [6.3223**]	Y = 4297.71 - 48.78 RH R ² = 0.4122 [2.5126*]	Y = 2159.89 - 24.97 RH R ² = 0.3073 [2.1064 NS]
DBM	Y = 109.17 - 3.25 Max. Temp. R ² = 0.4031 [2.8472*]	Y = 143.10 - 1.71 RH R ² = 0.6373 [3.9767**]	Y = -221.35+9.95 Max. Temp. R ² = 0.9386 [10.0006**] + Y ₂ = -221.35 - 4.21 Min. Temp. R ² = 0.9386 [3.6366**]
Hellula	Y = 41.79 - 1.77 Min. temp. R ² = 0.5213 [3.6152**]		
Crocidolomia	Y = 36.11 - 1.10 Max. Temp. R ² = 0.4791 [3.3229**]		

* : Significant at 0.01; ** : Significant at 0.05; NS : Non-Significant

Note : The last run equation in the step down regression analysis is given in the table.
Value in paranthesis indicate T-value

2.5081 at 0.01 probability (Table 10a). In case of Pride of India, minimum temperature and rainfall did not show any significant influence on the aphid incidence, hence, were eliminated. At the final step, relative humidity showed a significant impact on aphid incidence over maximum temperature which is indicated by a higher table value of 2.5126 as compared to 1.2857 of maximum temperature, which was then eliminated (Table 10b).

In the late plantings, in case of Golden Acre initially rainfall and relative humidity were eliminated as they did not exert any influence on the aphid incidence. In the third stage minimum and maximum temperature showed a non-significant relationship. Finally, minimum temperature was eliminated as it had a table value lesser than that of maximum temperature (Table 10a). In case of Pride of India, rainfall, maximum temperature and minimum temperature showed a non significant relationship on the incidence of aphid. Finally, relative humidity had a little influence on the aphid incidence but in a non-significant manner (Table 10b).

4.2.4.2 DBM

In the early planted crop, in case of Golden Acre, step down regression indicated that rainfall and maximum temperature did not have any significant impact on the incidence of DBM. In the third stage, it was seen that minimum temperature showed a significant influence on the DBM population build-up compared to relative humidity which was indicated by a higher table value of

3.8994 as compared to 2.1979 for relative humidity, which was therefore eliminated at a latter stage (Table 10a). In case of Pride of India, rainfall, relative humidity and minimum temperature had a non-significant influence on the population build up. Maximum temperature had a significant influence at 0.01 probability on the DBM population build-up (Table 10b).

In the normal planting, in variety Golden Acre, minimum temperature and rainfall were initially eliminated. In the third step, relative humidity showed a significant influence over maximum temperature which had a lower t-table value of 1.5040 as compared to 3.0677 for relative humidity, therefore the former was eliminated at the next stage (Table 10a). In case of Pride of India, in the third stage relative humidity showed a higher significant value of 3.9767 over maximum temperature which had a t-table value of 1.1214 which was eliminated at the next step (Table 10b).

In the late planting, minimum temperature showed a non-significant influence on DBM. In the next stage, it was seen that maximum temperature had a t-table value of 4.5001 which was significant at 0.05 probability and relative humidity had a t-value of 2.6625 at 0.01 probability. Therefore, it was concluded that maximum temperature and relative humidity together showed a significant influence on the population of DBM (Table 10a). In variety Pride of India only relative humidity and rainfall had a non significant influence whereas maximum temperature and minimum

temperature together had a significant influence on DBM population at 0.01 probability (Table 10b).

4.2.4.3 Hellula

The results of step down regression indicated that rainfall, relative humidity did not have a significant influence on the Hellula incidence (Table 10a). In the third step, maximum temperature had a significant influence on the Hellula infestation over minimum temperature as indicated by higher t-table value of 4.2584 for maximum temperature as against 2.0913 for minimum temperature which was latter eliminated at the final stage in case of Golden Acre. In case of Pride of India, rainfall relative humidity and maximum temperature had a non significant influence on the Hellula incidence. Only minimum temperature showed a significant influence on the Hellula population build-up at 0.01 probability in the early planting (Table 10b).

4.2.4.4 Crocidolomia

The results of step down regression (Table 10a) indicated that relative humidity and rainfall had a non significant influence on the Crocidolomia incidence. In the third stage, maximum temperature had a significant influence over minimum temperature which is indicated by a higher t-table value of 4.6337 for maximum temperature as against 1.2321 for minimum temperature which was eliminated at the final stage in variety Golden Acre. In case of Pride of India rainfall, relative humidity and minimum temperature had a non significant influence.

Maximum temperature alone had a significant influence on the population build-up of Crociodolomia during early planting (Table 10b).

4.3 DISTRIBUTION PATTERN OF DIFFERENT PESTS ON CABBAGE

The distribution pattern of different pests was determined by estimating 25 plant samples selected at random from each quadrat thus covering the entire field. The observations were taken starting from the first week after transplanting at weekly intervals until the crop was harvested. A total of 14, 11 and 12 sets of observations were recorded in early, normal and late planted crops respectively.

4.3.1 Frequency distribution

After arranging the data in frequency table, the mean and variance of pests infesting the cabbage crop are only presented in Tables 11 to 16.

4.3.1.1 Aphid

The mean values for cabbage aphid population on Golden Acre ranged in between 0.80 to 118.72, 1.76 to 56.32 and 0.44 to 39.40 in early, normal and late planted crops respectively (Table 11). Whereas, in Pride of India, the mean values were in between 1.04 to 125.76 in early plantings, 1.64 to 53.92 in normal plantings and 0.40 to 42.04 in late planted crop (Table 12).

It was also observed that mean aphid populations was higher in Pride of India. It is also evident from the Tables 11

Table 11: Weekly mean (\bar{x}) and variance (S^2) of the cabbage aphid B. brassicae in Var. Golden acre

Age of the crop (days)	Early		Normal		Late	
	Mean (\bar{x})	Variance (S^2)	Mean (\bar{x})	Variance (S^2)	Mean (\bar{x})	Variance (S^2)
7	0.00	0.00	1.76	6.77	0.44	1.17
14	2.56	27.17	6.08	50.99	2.40	9.42
21	5.56	67.34	21.04	327.54	10.04	174.46
28	3.20	38.00	21.12	458.69	9.96	176.21
35	0.80	4.58	29.32	1039.81	19.60	468.92
42	7.48	174.18	50.76	869.94	38.64	1041.66
49	12.12	190.28	44.16	654.14	38.92	637.24
56	24.72	524.96	51.88	520.44	30.16	452.97
63	57.20	2050.67	56.32	580.81	35.80	192.92
70	118.72	7156.79	43.12	497.53	39.40	261.67
77	117.72	9967.38	38.28	462.54	27.36	171.82
84	38.04	1008.71	-	-	24.08	253.49
91	36.16	417.39	-	-	-	-
98	65.52	3842.59	-	-	-	-

Table 12: Weekly mean (\bar{x}) and variance (S^2) of the cabbage aphid B. brassicae in var. Pride of India

Age of the crop (days)	Early		Normal		Late	
	Mean (\bar{x})	Variance (S^2)	Mean (\bar{x})	Variance (S^2)	Mean (\bar{x})	Variance (S^2)
7	0.00	0.00	1.64	7.49	0.40	1.75
14	1.04	6.29	7.44	50.59	1.60	4.83
21	3.52	55.34	12.84	325.31	10.52	162.26
28	1.92	16.16	10.36	185.57	9.48	209.18
35	7.60	677.08	26.60	342.92	18.80	305.08
42	13.16	422.97	53.92	1320.58	36.24	976.11
49	20.80	479.42	47.16	571.22	42.04	416.54
56	30.20	685.67	50.36	751.66	39.20	471.33
63	29.16	778.72	46.20	551.92	34.12	218.94
70	68.00	6262.42	49.08	468.58	43.80	364.42
77	125.76	14291.86	42.16	495.06	39.08	297.58
84	77.08	3070.74	-	-	23.04	141.62
91	40.40	294.17	-	-	-	-
98	90.52	4652.26	-	-	-	-

and 12 that the values of variance are greater than the corresponding mean values ($S^2 > \bar{X}$) for all the weeks in all the plantings in both the varieties, hence the aphid population is clumped or aggregated, i.e., it holds good to a negative binomial distribution.

This trend of distribution of aphids, with their spread in lower numbers on majority of the sampling units and in higher numbers to a fewer ones is observed in almost all weeks indicate their aggregating nature of distribution confirming the negative binomial.

4.3.1.2 DBM

The DBM larvae were not noticed on Golden Acre and Pride of India in first, fourth and seventh week age of the crop in the early planting (Tables 13 and 14), In normal planting, it was found infesting the crop through out crop growth in both the varieties whereas in the late planting, the infestation started from first week after transplanting in both the varieties. The mean values in Golden Acre ranged in between 0.04 to 1.28; 0.12 to 1.44 and 0.12 to 2.64 in early, normal and late planted crops respectively, while in Pride of India, the values ranged in between 0.04 to 1.28; 0.04 to 1.60 and 0.04 to 3.20 in early, normal and late plantings respectively.

From the perusal of the data, it is clearly seen that the mean DBM larval population was greater than variance in second, fifth and sixth week of early plantings in Golden Acre

Table 13: Weekly mean (\bar{x}) and variance (S^2) of the DBM variety Golden acre

Age of the crop (days)	Early		Normal		Late	
	Mean (\bar{x})	Variance (S^2)	Mean (\bar{x})	Variance (S^2)	Mean (\bar{x})	Variance (S^2)
7	0.00	0.00	0.12	0.19	0.12	0.19
14	0.08	0.04	0.48	1.01	0.24	0.27
21	0.24	0.27	0.72	2.13	0.44	0.67
28	0.00	0.00	0.56	1.17	0.72	1.38
35	0.04	0.02	1.28	7.88	0.64	1.24
42	0.04	0.02	1.20	4.17	0.92	2.16
49	0.00	0.00	1.20	2.42	1.36	0.49
56	0.56	1.34	1.20	3.25	1.32	3.31
63	0.36	0.66	1.36	3.82	1.92	3.10
70	0.28	0.38	1.44	4.09	1.44	4.26
77	0.80	2.33	1.20	2.25	2.64	7.32
84	1.28	4.54	-	-	2.60	8.50
91	0.68	1.39	-	-	-	-
98	0.60	1.00	-	-	-	-

Table 14: Weekly mean (\bar{x}) and variance (S^2) of the DBM in variety Pride of India

Age of the crop (days)	Early		Normal		Late	
	Mean (\bar{x})	Variance (S^2)	Mean (\bar{x})	Variance (S^2)	Mean (\bar{x})	Variance (S^2)
7	0.00	0.00	0.12	0.23	0.04	0.20
14	0.04	0.20	0.48	0.62	0.40	0.92
21	0.76	11.52	0.48	1.59	0.72	2.21
28	0.00	0.00	0.36	0.66	1.00	2.17
35	0.04	0.20	0.04	0.20	0.76	1.61
42	0.04	0.20	1.44	4.51	0.64	1.82
49	0.00	0.00	0.80	1.67	1.40	4.50
56	0.08	0.40	1.00	2.17	1.40	3.67
63	1.28	3.79	1.36	3.49	1.60	3.58
70	0.36	0.57	1.60	3.58	1.44	2.92
77	1.24	4.44	1.32	2.39	1.72	5.04
84	0.84	1.97	-	-	3.20	9.08
91	1.08	2.83	-	-	-	-
98	0.76	1.44	-	-	-	-

and Pride of India indicating a positive binomial distribution (Tables 13 and 14).

In all the plantings in both the varieties except above mentioned weeks, the mean values were less than variance indicating aggregated behaviour of the DBM. The Pride of India variety recorded maximum larvae in comparison to Golden Acre variety throughout experimentation.

4.3.1.3 Cabbage head borer

The mean larval population of Hellula was found to be less than variance in both the varieties in early plantings and the larvae were not observed during normal and late plantings. The larvae appeared one month before the harvest and their behaviour confirmed the negative binomial (Table 15). The mean values ranged in between 0.80 to 0.92 and 0.56 to 1.08 in Golden Acre and Pride of India respectively.

4.3.1.4 Cabbage leaf webber

The leaf webber larvae appeared for a period of four weeks before harvest in early plantings only and the mean values were found to be less than variance in both the varieties. The mean values ranged in between 1.16 to 1.60 on Golden acre. In Pride of India, the mean values ranged in between 1.16 to 1.60 (Table 16). This tendency of distribution of Crocidolomia indicates the clumped behaviour of larval distribution.

Table 15: Weekly mean and variance of Hellula on two cabbage varieties

Age of the crop (days)	Golden Acre		Pride of India	
	Mean (x)	Variance (S^2)	Mean (x)	Variance (S^2)
77	0.92	4.49	1.04	4.29
84	0.80	2.92	0.56	1.59
91	0.84	2.97	1.08	3.83
98	0.84	2.31	1.04	2.96

Table 16: Weekly mean and variance of Crocidolomia on two cabbage varieties

Age of the crop (days)	Golden Acre		Pride of India	
	Mean (x)	Variance (S^2)	Mean (x)	Variance (S^2)
77	1.32	4.81	1.36	3.49
84	1.60	3.17	1.60	3.17
91	1.56	3.92	1.56	3.92
98	1.16	2.64	1.16	2.64

4.3.2 Estimation of dispersion parameter 'K'

Fitting of negative binomial distribution was further attempted on all the pests collected in each week of crop growth during three seasons. The value of dispersion parameter 'K' (Tables 17 to 19) were based on mean (\bar{X}) and variance (S^2) of each week and were calculated using Moment estimate of 'K'; 'K' from proportion of zeroes and trial and error method as explained in the previous chapter. The value of 'K' obtained by Trial and Error Method is considered as real and accurate in ecological studies (Southwood, 1978). Hence, these values are only presented for all the pests under study throughout the text.

4.3.2.1 Aphid

The 'K' values obtained are presented in Table 17 and depicted in Fig. 8a & b. The values of 'K' at different crop stages on Golden Acre ranged from 0.09 to 0.20; 0.13 to 0.19 and 0.10 to 0.37 in early, normal and late plantings respectively (Fig.8a). In Pride of India, the 'K' values ranged in between 0.06 to 0.19; 0.13 to 0.37 and 0.06 to 0.23 in early, normal and late plantings, respectively (Fig.8b).

During all plantings, the value of dispersion parameter 'K' showed an intermittent decrease and increase reflecting a change from less clumped to more clumped distribution and vice-versa.

Table 17: Determination of dispersion parameter 'K' by Trial and Error method for cabbage aphid in different plantings

Weeks the crop	Age of (days)	VAR: GOLDEN ACRE			VAR: PRIDE OF INDIA		
		Early	Normal	Late	Early	Normal	Late
1	7	0.00	0.17	0.09	0.00	0.13	0.06
2	14	0.09	0.19	0.37	0.08	0.37	0.21
3	21	0.11	0.18	0.27	0.06	0.13	0.16
4	28	0.16	0.16	0.17	0.16	0.13	0.14
5	35	0.14	0.13	0.12	0.06	0.18	0.15
6	42	0.09	0.17	0.14	0.09	0.15	0.13
7	49	0.10	0.16	0.17	0.11	0.17	0.15
8	56	0.15	0.17	0.21	0.15	0.17	0.19
9	63	0.19	0.16	0.19	0.14	0.17	0.20
10	70	0.15	0.16	0.19	0.13	0.17	0.18
11	77	0.14	0.16	0.20	0.14	0.18	0.20
12	84	0.20	-	0.21	0.16	-	0.22
13	91	0.19	-	-	0.19	-	-
14	98	0.17	-	-	0.14	-	-

DISPERSION PARAMETER "K" FOR APHID (VARIETY GOLDEN ACRE)

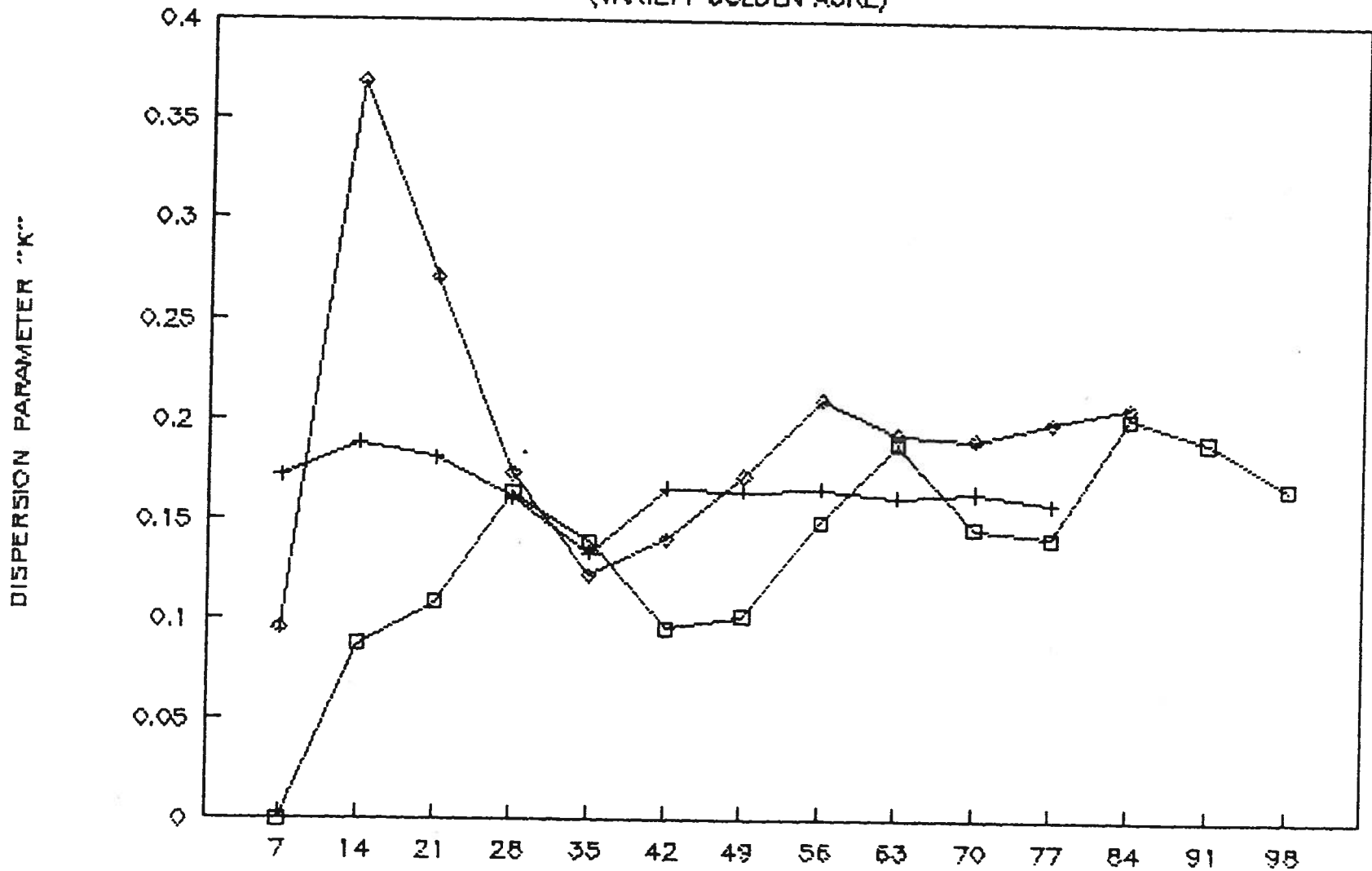


FIG. 8a : DAYS AFTER TRANSPLANTING

□ EARLY PLANTINGS. + NORMAL PLANTINGS ◇ LATE PLANTINGS

DISPERSION PARAMETER "K" FOR APHID

(VARIETY PRIDE OF INDIA)

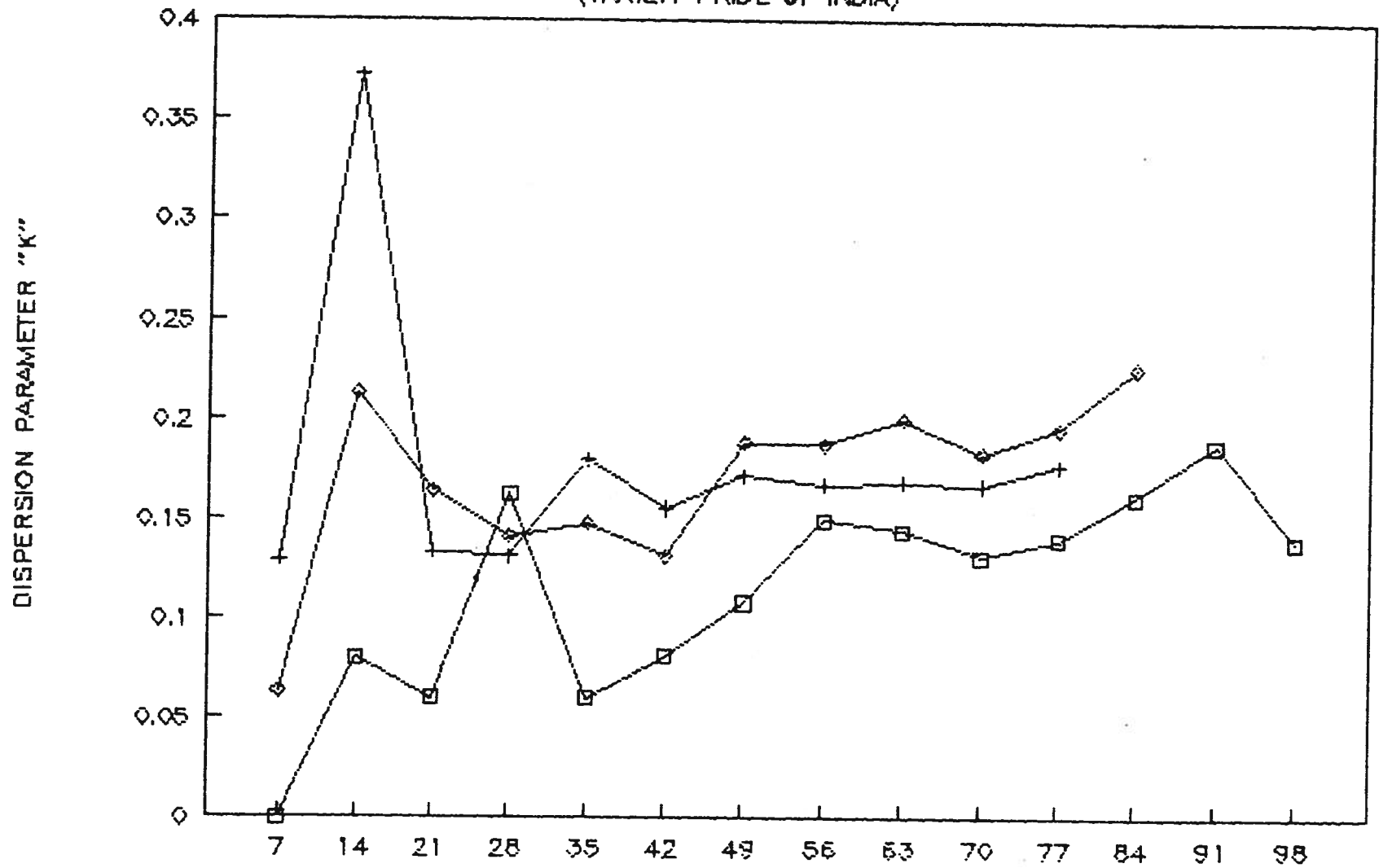


FIG. 8b : DAYS AFTER TRANSPLANTING

□ EARLY PLANTINGS. + NORMAL PLANTINGS ◇ LATE PLANTINGS

The maximum value of 'K' a dispersion parameter never went beyond 8, thus further confirming aggregated nature of distribution of aphid on the cabbage.

4.3.2.2 DBM

The 'K' values obtained are presented in the Table 18 and are depicted in Figs. 9a & b. The values of 'K' at different crop stages on variety Golden Acre ranged from 0.13 to 1.06; 0.12 to 0.82 and 0.22 to 1.06 in early, normal and late plantings. In case of Pride of India, during early, normal and late plantings the 'K' value ranged from 0.04 to 0.52; 0.23 to 0.78 and 0.21 to 5.76.

During all plantings in both the varieties the value of dispersion parameter, 'K' showed an intermittent decrease and increase reflecting a change from less clumped to more clumped distribution and vice-versa.

4.3.2.3 Hellula

The 'K' values obtained by Trial and Error method are presented in the Table 19 and depicted in Fig. 10. The values of 'K' ranged from 0.11 to 0.42 in Golden Acre and 0.09 to 0.39 in variety Pride of India.

4.3.2.4 Crocidolomia

The 'K' values are presented in Table 19 and depicted in Fig. 11. The values of 'K' obtained for four weeks of observa-

Table 18: Determination of dispersion parameter 'K' by Trial and Error method for DBM in different plantings

Weeks the crop (days)	Age of	VAR: GOLDEN ACRE			VAR: PRIDE OF INDIA		
		Early	Normal	Late	Early	Normal	Late
1	7	0.00	*	*	0.00	*	*
2	14	*	0.36	1.06	*	*	0.21
3	21	1.06	0.50	0.63	0.04	0.23	0.23
4	28	0.00	0.36	0.42	0.00	0.27	0.39
5	35	*	0.17	0.46	*	*	0.37
6	42	*	0.28	0.75	*	0.33	0.36
7	49	0.00	0.61	0.21	0.04	0.36	0.35
8	56	0.23	0.40	0.58	*	0.23	0.54
9	63	0.27	0.23	*	0.45	0.47	0.71
10	70	0.55	0.25	0.22	0.52	0.71	0.27
11	77	0.13	0.82	0.56	0.16	0.78	0.22
12	84	0.16	-	0.28	0.32	-	0.34
13	91	0.41	-	-	0.34	-	-
14	98	0.55	-	-	0.53	-	-

* : indicates positive binomial

Table 19: Dispersion parameter 'K' by trial and error method for cabbage head borer and cabbage leaf webber

S.No.	Age of crop (days)	<u>HELLULA</u>		<u>CROCIDOLOMIA</u>	
		Golden Acre	Pride of India	Golden Acre	Pride of India
11	77	0.11	0.09	0.44	0.21
12	84	0.15	0.13	0.33	0.33
13	91	0.29	0.14	0.53	0.53
14	98	0.42	0.39	0.45	0.45

DISPERSION PARAMETER "K" FOR DBM (VARIETY GOLDEN ACRE)

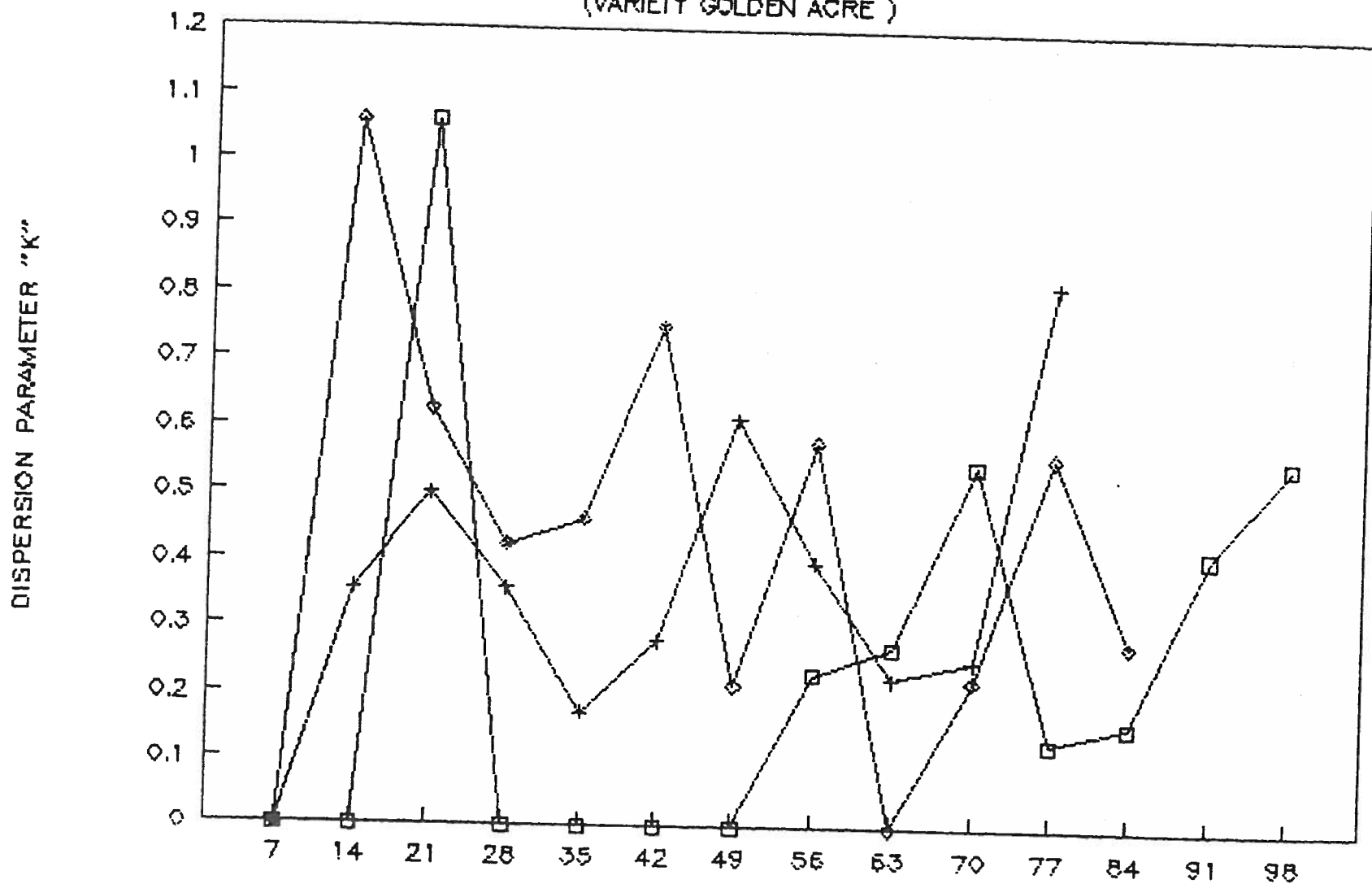


FIG. 9a : DAYS AFTER TRANSPLANTING

□ EARLY PLANTINGS.
+ NORMAL PLANTINGS
◇ LATE PLANTINGS

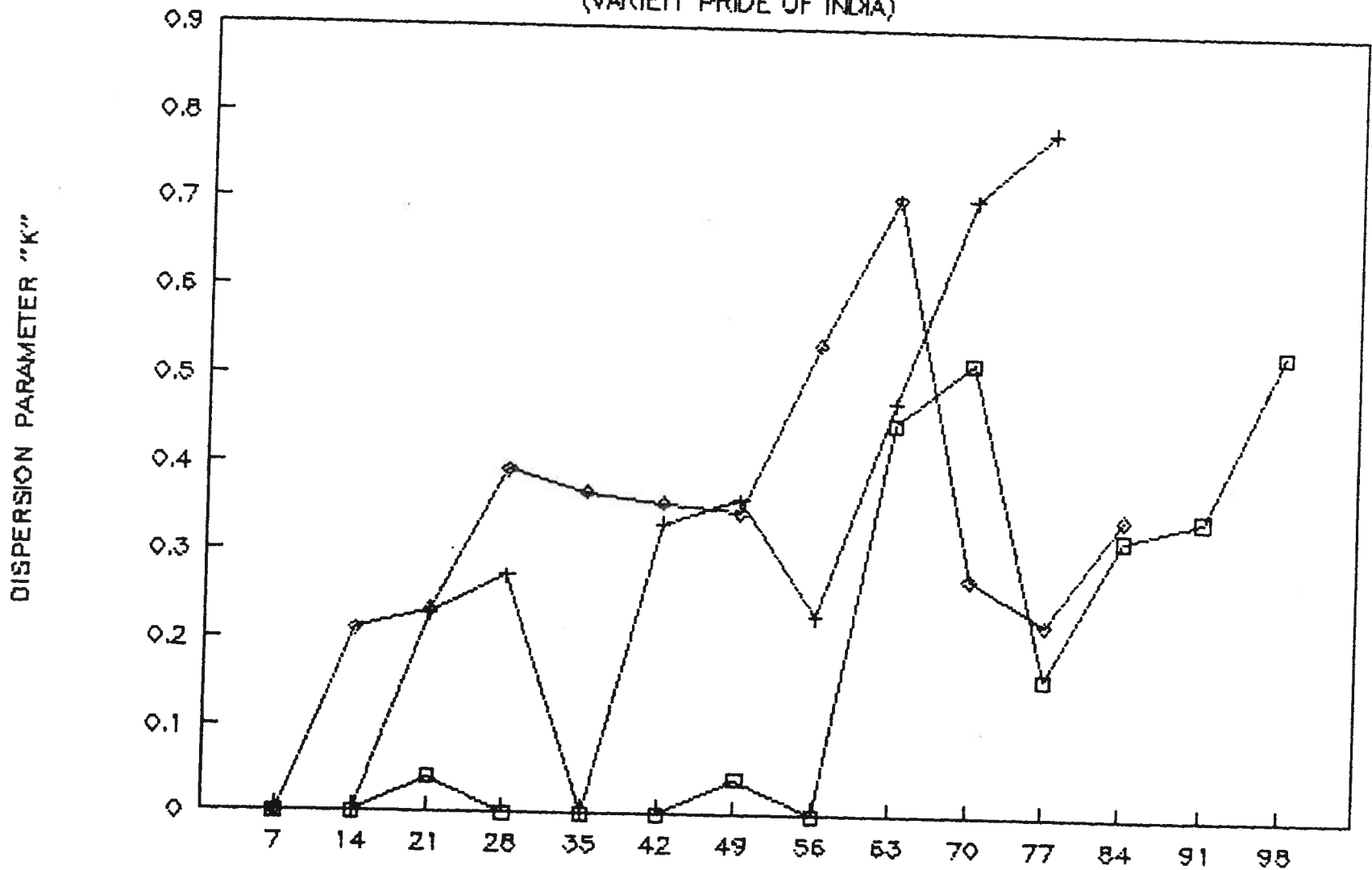


FIG. 96 : DAYS AFTER TRANSPLANTING

□ EARLY PLANTINGS. + NORMAL PLANTINGS ◇ LATE PLANTINGS

DISPERSION PARAMETER "K" FOR HELLULA

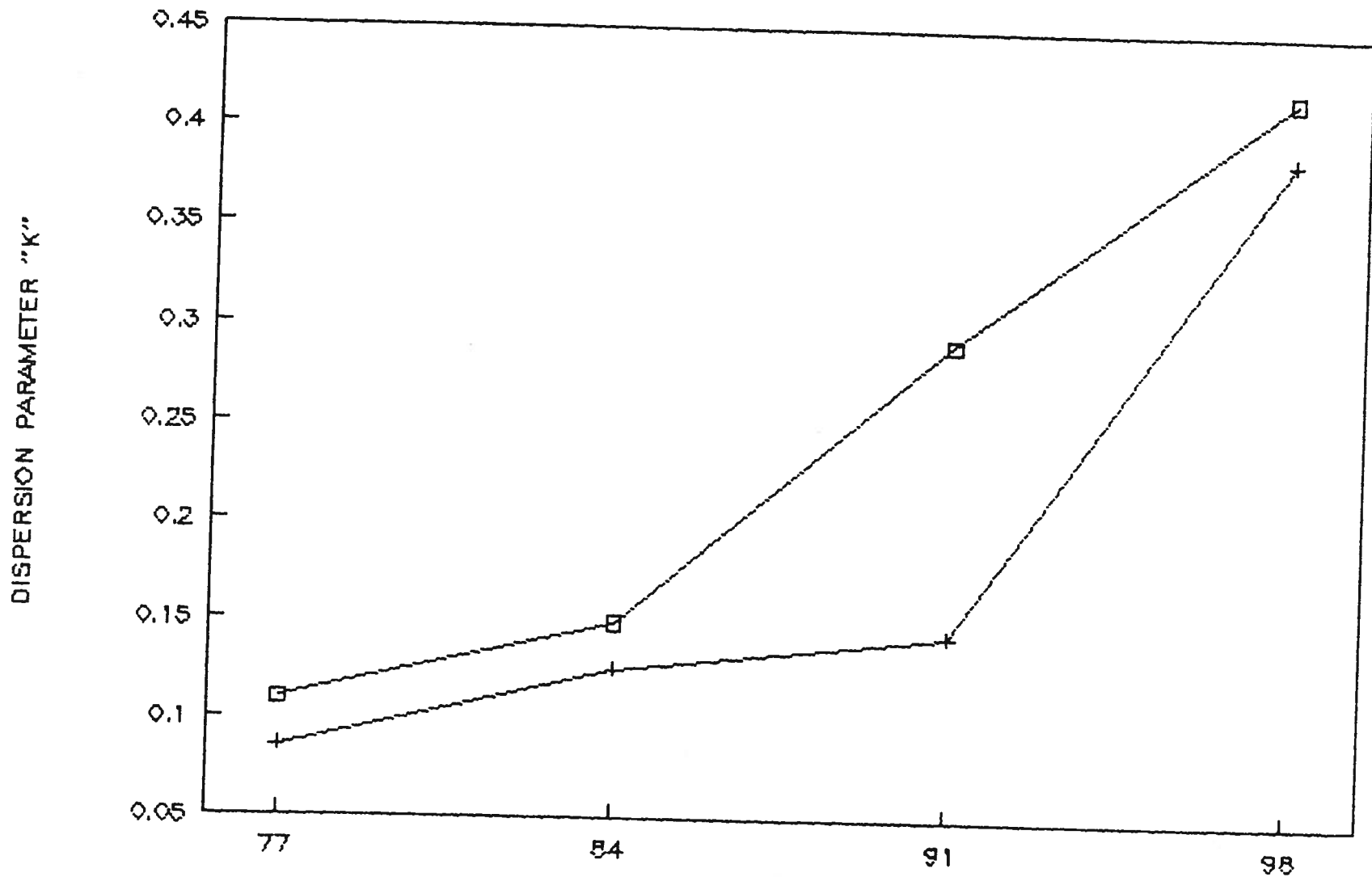


FIG. 10 : DAYS AFTER TRANSPLANTING
□ GOLDEN ACRE + PRIDE OF INDIA

DISPERSION PARAMETER "K" FOR CROCIDOLOMIA

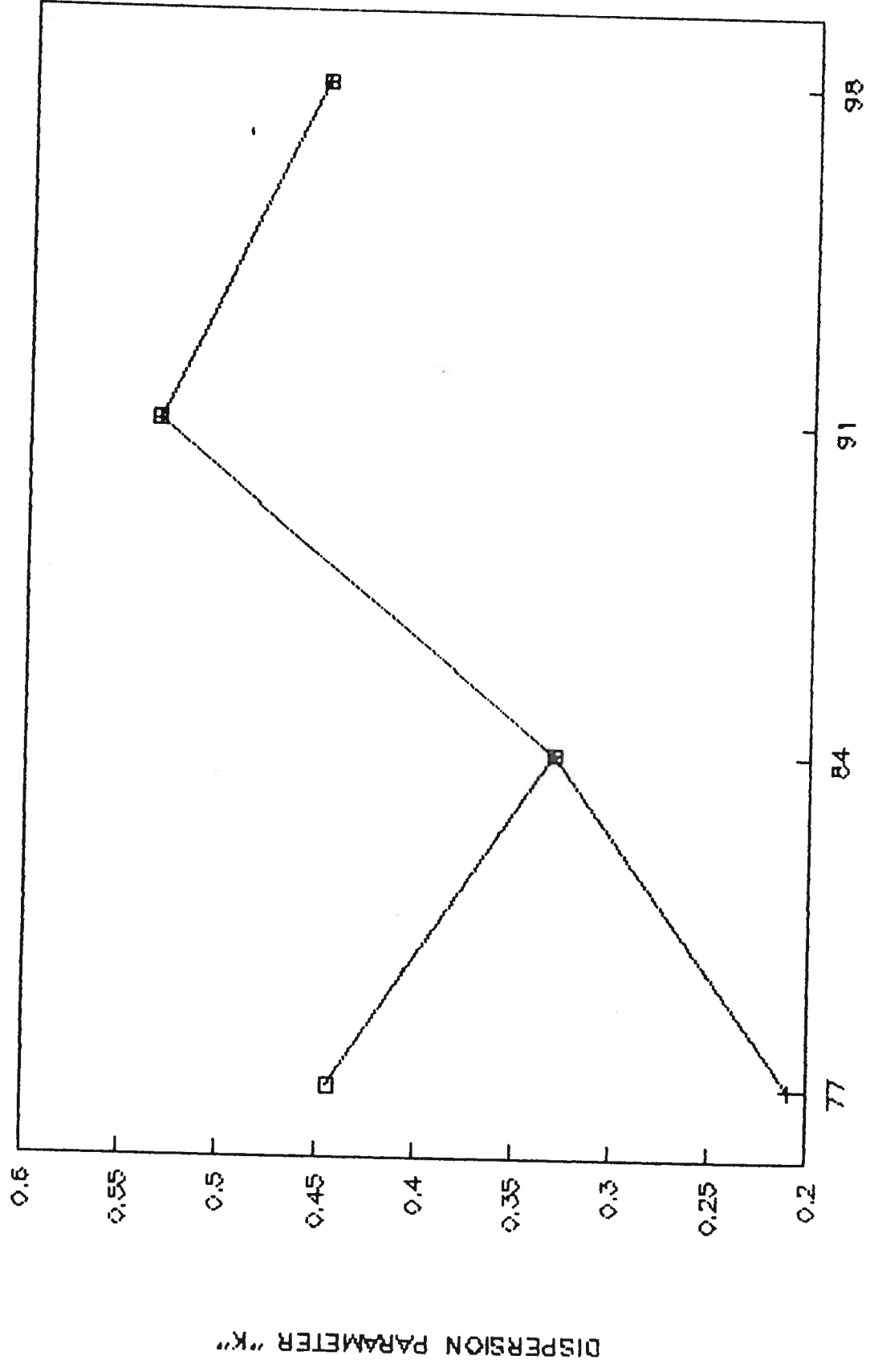


FIG. 11 : DAYS AFTER TRANSPLANTING
□ GOLDEN ACRE + PRIDE OF INDIA

tion are 0.44, 0.33, 0.53 and 0.45 in Golden Acre at 77, 84, 91 and 98, DAT crop age respectively. In Pride of India. For the same period the 'K' values were 0.21, 0.33, 0.53, and 0.45.

In both the varieties, the dispersion parameter 'K' went on increasing for both the pests indicating a gradual reduction in the aggregated nature of head borer and leaf webber and spread of the population to more and more sampling units in the field.

4.3.3 Determination of common 'K' (K_c) by moments and regression method

A separate common clumping parameter (K_c) was worked out as mentioned in Materials and Methods for all the pests by moments and regression method and the results are presented below.

4.3.3.1 Aphid

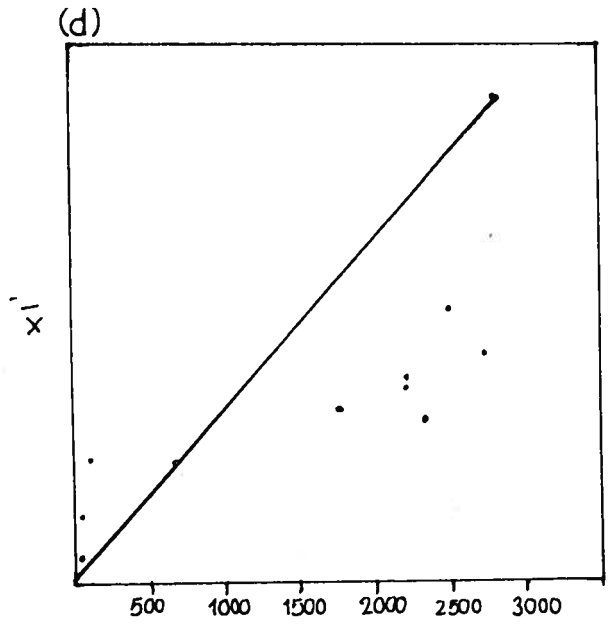
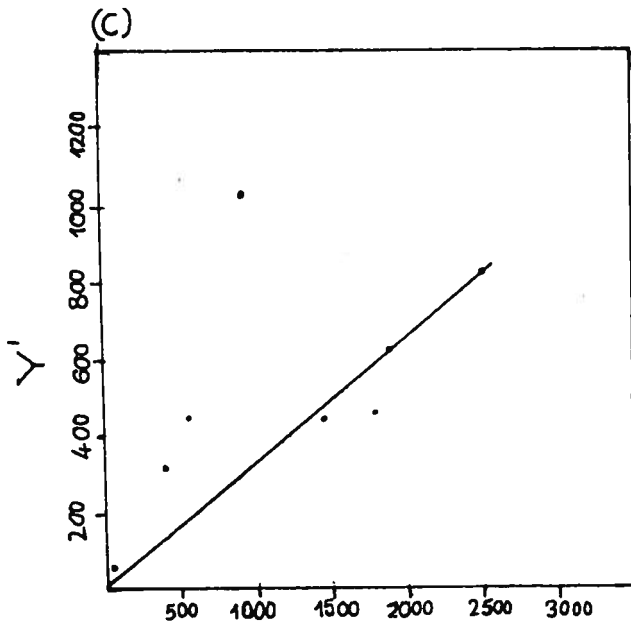
The K_c values thus obtained are 1.53, 3.02 and 2.40 in Golden Acre during early, normal and late plantings and 1.20, 3.14 and 3.11 for Pride of India and the regression line of Y' on X' was fitted by joining the lowest and highest points on the line (Fig.12).

The regression estimate of common 'K' (K_c) was made to test whether this is true representative of various 'K' values with the help of statistics Y' and X'.

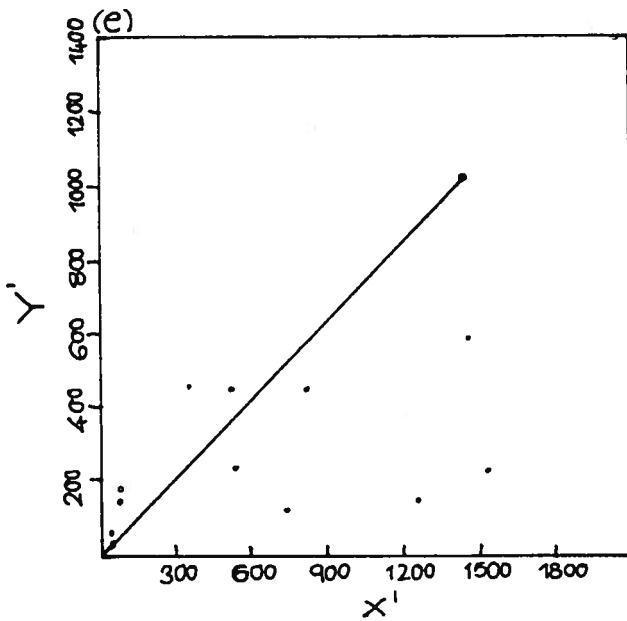
The values of dispersion parameter 'K' and its reciprocal $1/K$ are frequently used as indices of dispersion. As



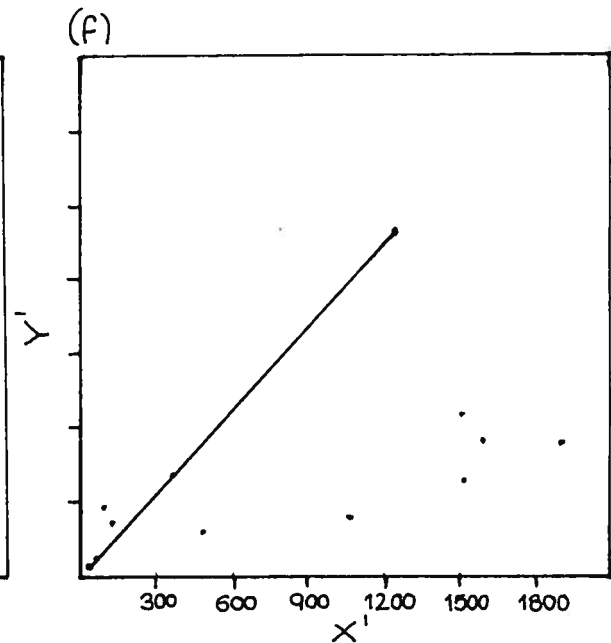
Fig-12. Regression Line of Y' on x' for Cabbage Aphid (Early Planting)



Normal Planting



Golden Acre



Pride of India

Late Planting

Fig-12. Regression Line of Y' on x' for Cabbage Aphid

$1/K$ approaches zero and 'K' approaches infinity, then distribution converges to Poisson Series. Conversely, if clumping increases, $1/K$ approaches infinity and distribution converges to the logarithmic series. The observed values of 'K' and its reciprocal $1/K$ for cabbage aphid in the present investigation sloped towards contagiousness of the population. A graph was also tried by plotting mean (\bar{X}) and $1/K$ for all the weeks (Figs.13a to 13f) and it was observed that there is no relationship between mean (\bar{X}) and $1/K$ and therefore the calculation of common K (K_c) is justified. The estimate of the slope of the regression is presented below for both varieties in three plantings.

$1/K_c$ during plantings	Golden Acre	Pride of India
Early	0.65	0.84
Normal	0.33	0.32
Late	0.42	0.32

4.3.3.2 DBM

The ' K_c ' values thus obtained in case of variety Golden Acre are 0.45; 0.68 and 0.90 for early, normal and late plantings and in case of Pride of India, the values were 0.18, 0.81 and 1.14 for early, normal and late plantings, respectively. The regression line of 'Y' on 'X' was fitted by joining the lowest and highest points of the line (Fig.14).

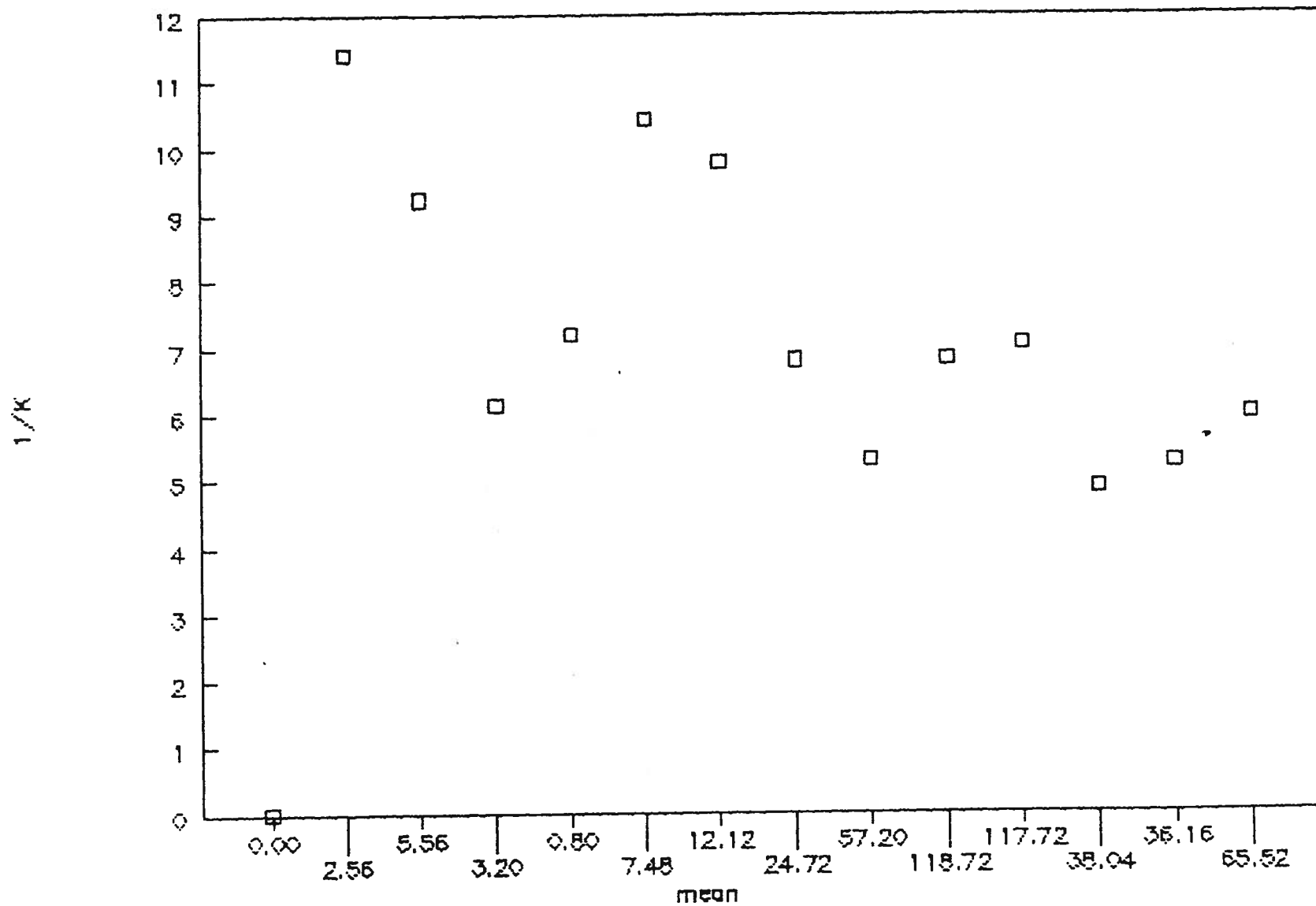


Fig 13 a. Relation of 1/K to mean (\bar{x}) for aphid in early planting (Golden Acre)

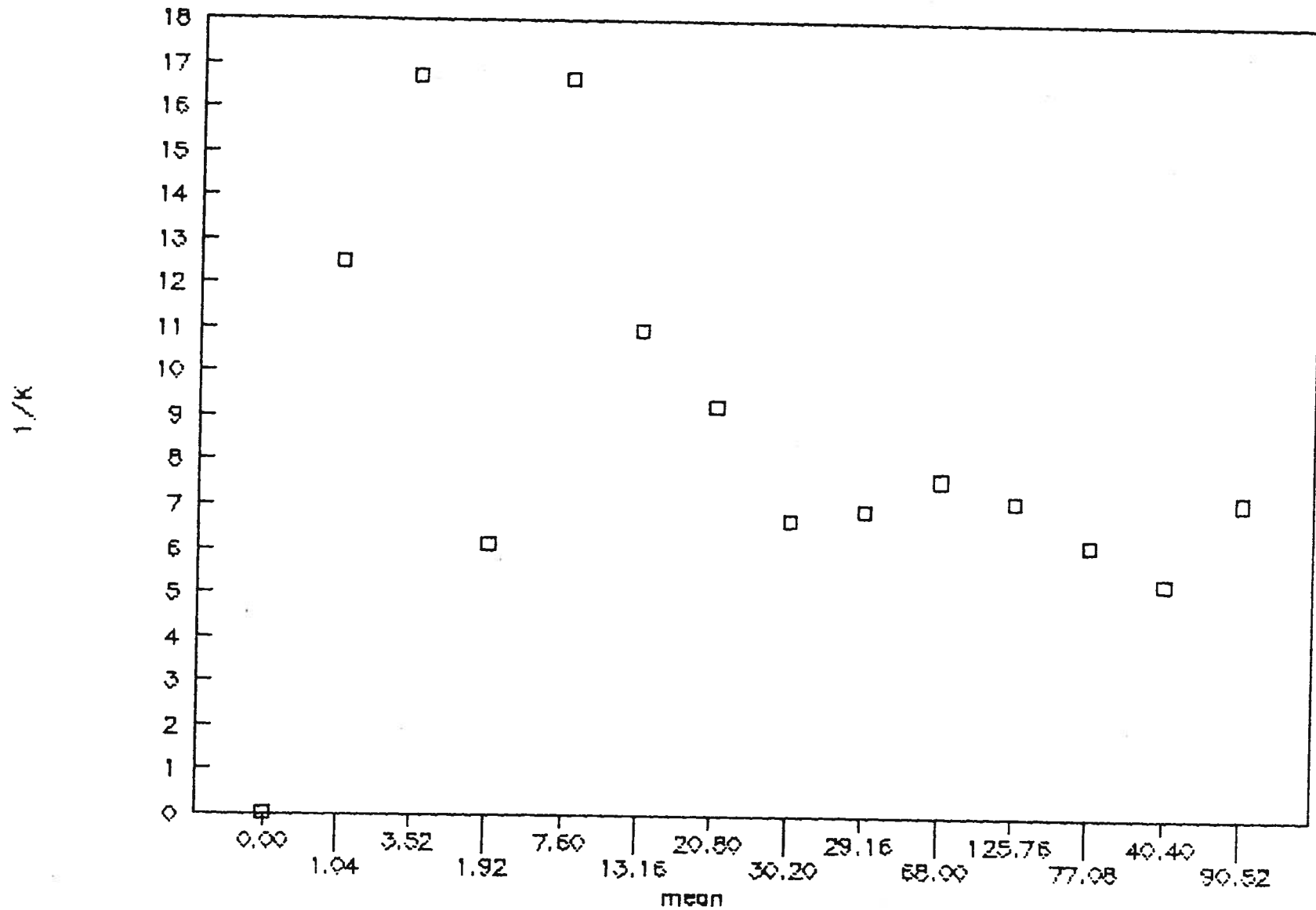


Fig 13 b. Relation of $1/k$ to mean (\bar{x}) for aphid in early planting (Pride of India)

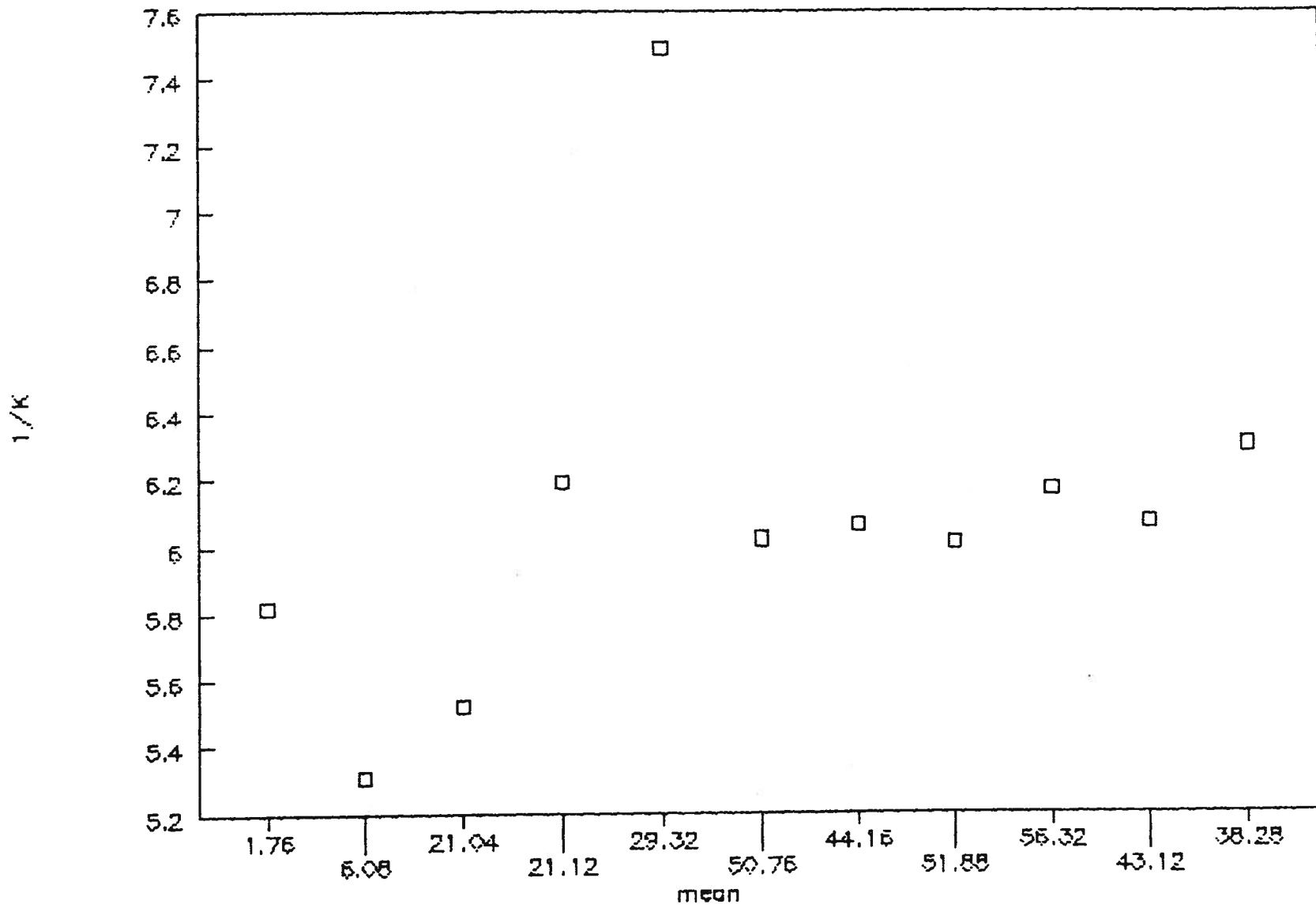


Fig 13 c. Relation of $1/k$ to mean (\bar{x}) for aphid in normal planting (Golden Acre)

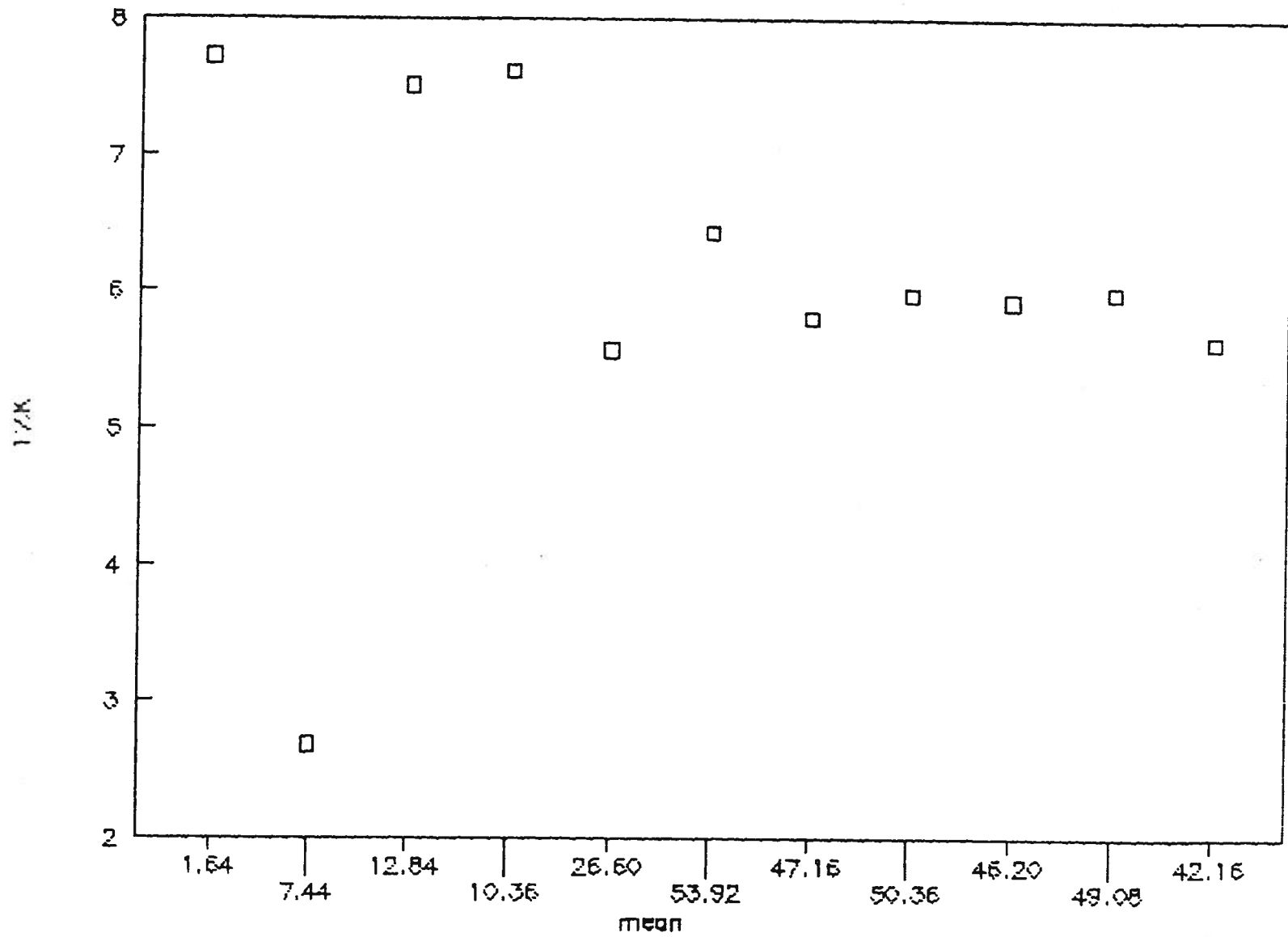


Fig 13 d. Relation of $1/k$ to mean (\bar{x}) for aphid in normal planting (Pride of India)

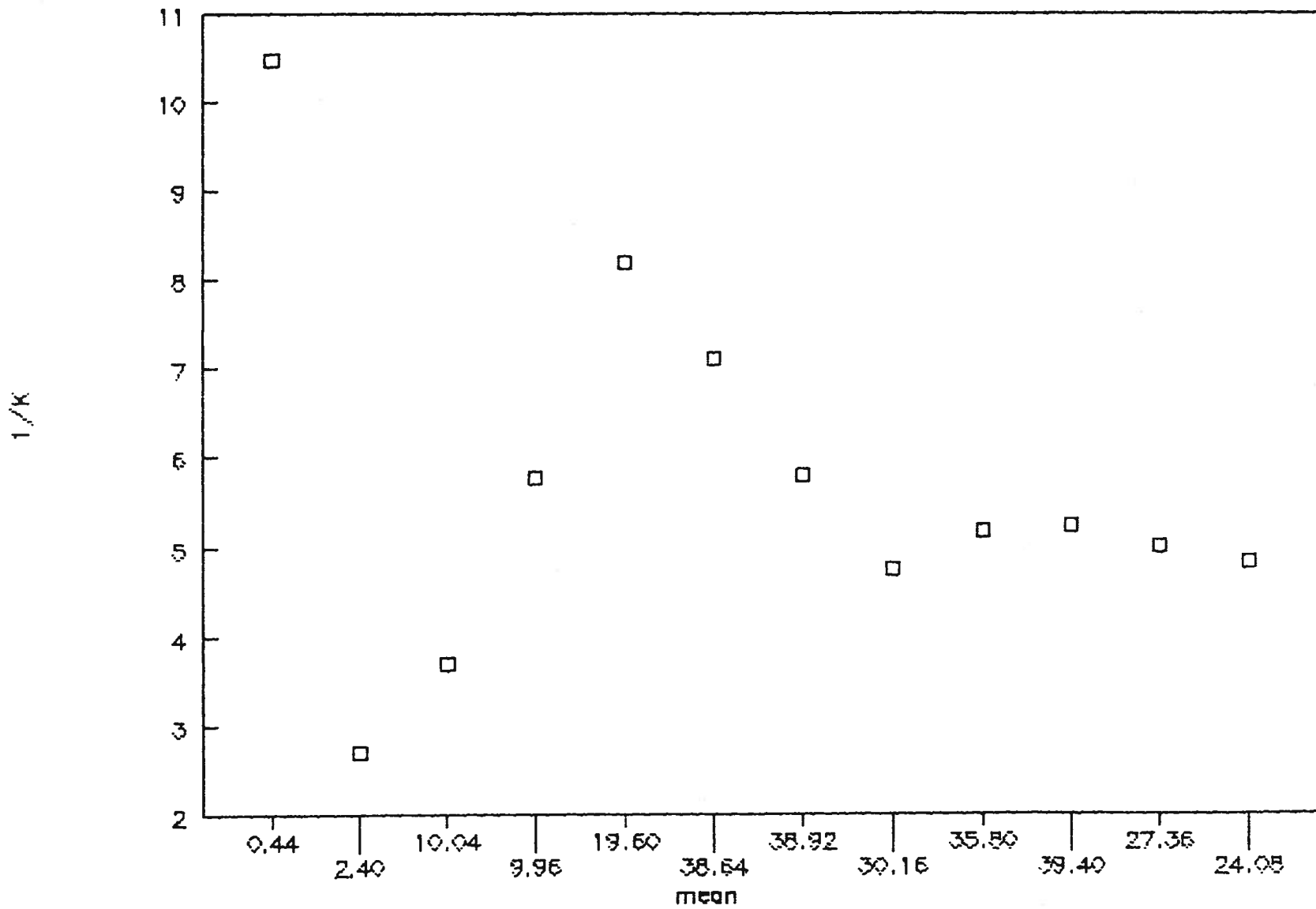


Fig 13 e. Relation of $1/k$ to mean (\bar{x}) for aphid in late planting (Golden Acre)

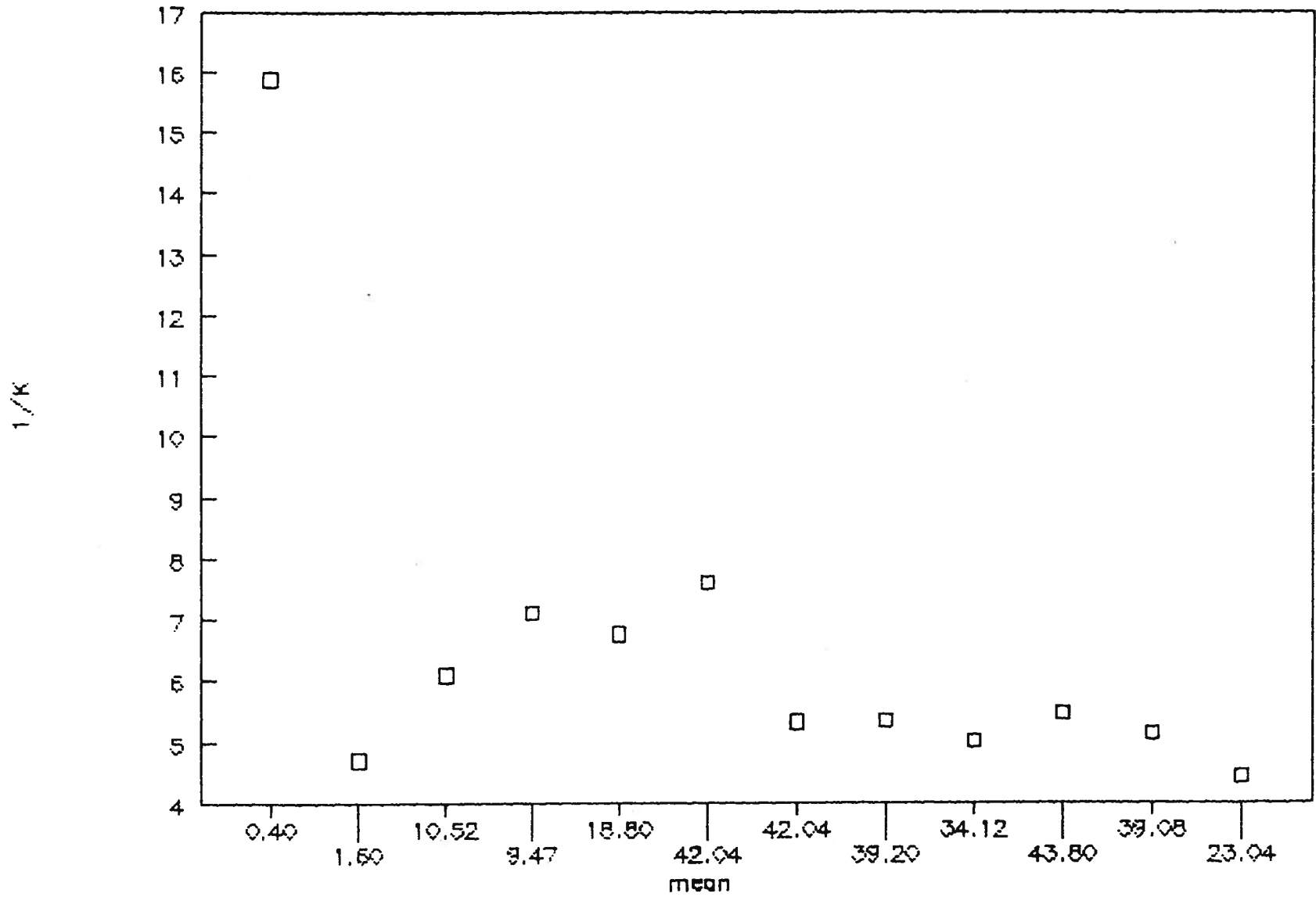
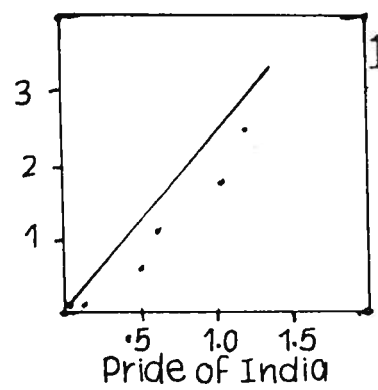
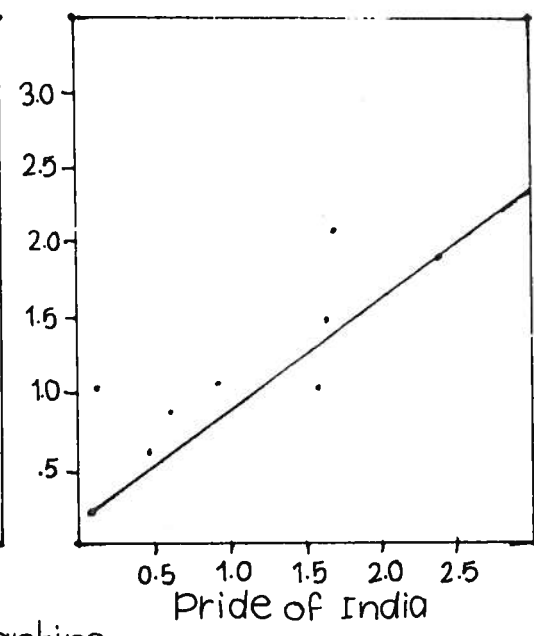
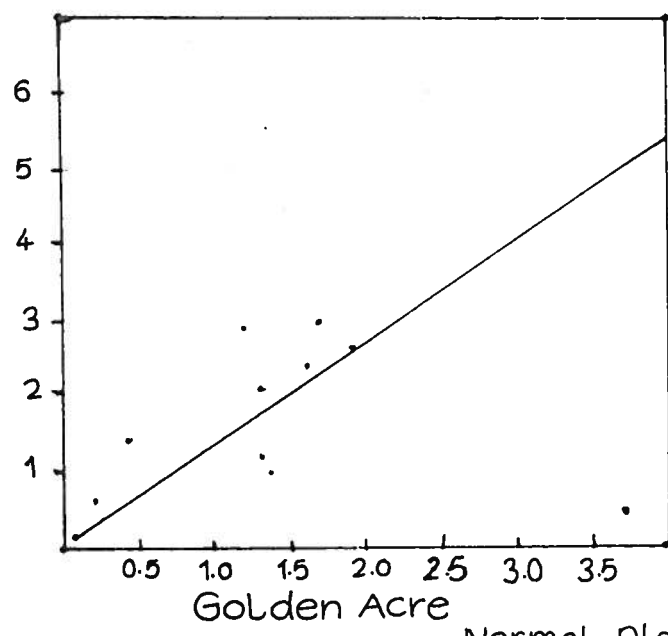


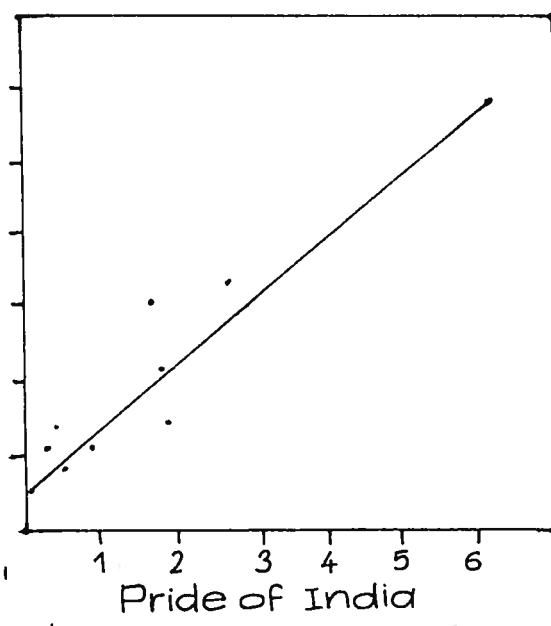
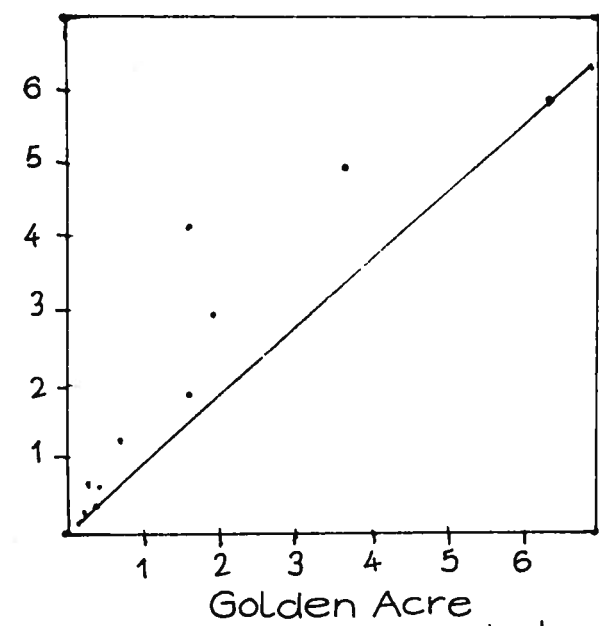
Fig 13 f. Relation of $1/k$ to mean (\bar{x}) for aphid in late planting (Pride of India)



Early Planting



Normal Planting



Late Planting

Fig-14. Regression Line of Y' on X' for DBM

The observed value of 'K' and its reciprocal '1/K' for DBM sloped towards contagiousness of the population and it was observed that there was no relationship between mean and 1/K (Figs.15a to 15f). The slope of the regression obtained is presented below.

1/K for DBM during different plantings	Golden Acre	Pride of India
Early	2.22	5.64
Normal	1.47	1.24
Late	1.11	0.88

4.3.3.3 Hellula

The K_c values obtained were 0.26 and 0.35 in Golden Acre and Pride of India, respectively. The regression line on Y' on X' was fitted by joining the lowest and highest points on the line (Fig.16^{ab}). The reciprocal of K, i.e. '1/K' was calculated. The observed value of 'K' and its reciprocal '1/K' for Hellula sloped towards contagiousness of the population and 1/K for Golden Acre and Pride of India is 3.89 and 2.85, respectively.

4.3.3.4 Crocidolomia

The K_c values thus obtained are 0.84 and 1.02 in case of variety Golden Acre and variety Pride of India respectively. The regression line on Y' on X' was fitted by joining the lowest and highest points on the line (Fig. 16^{cd}). The reciprocal of K i.e.

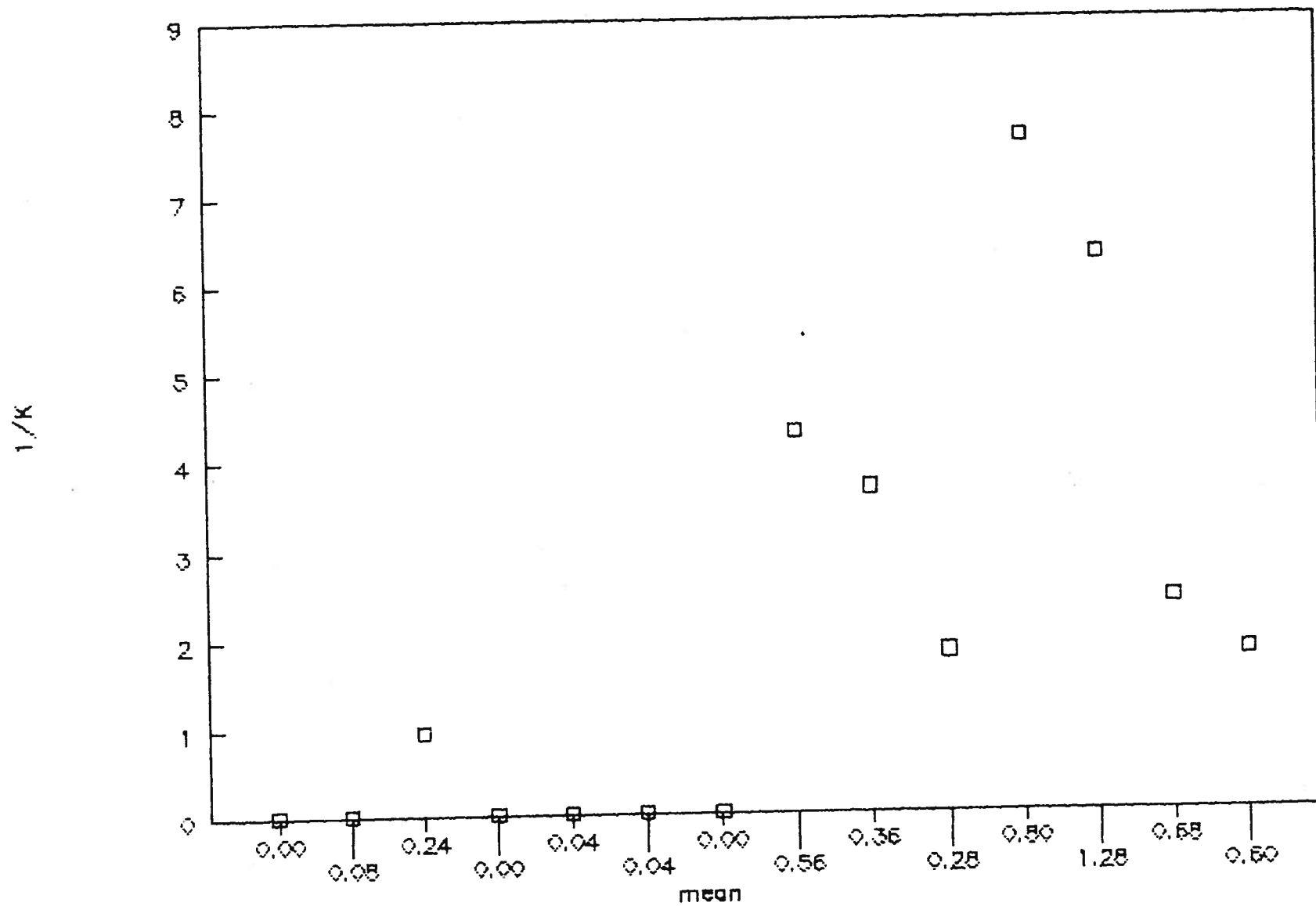


Fig 15 a. Relation of $1/k$ to mean (\bar{x}) for DBM in early planting (Golden Acre)

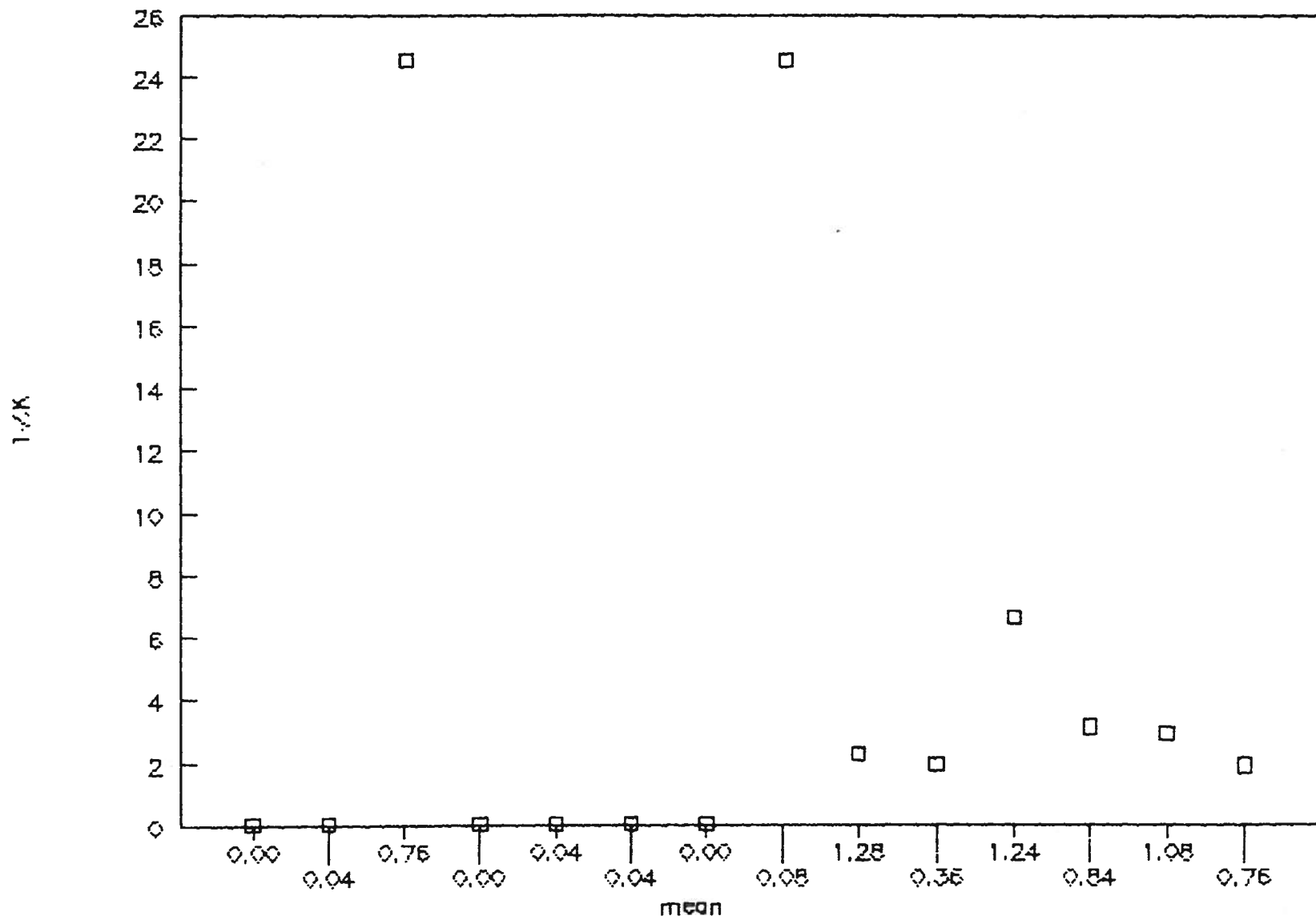


Fig 15 b. Relation of 1/k to mean (x) for DEM in early planting (Pride of India)

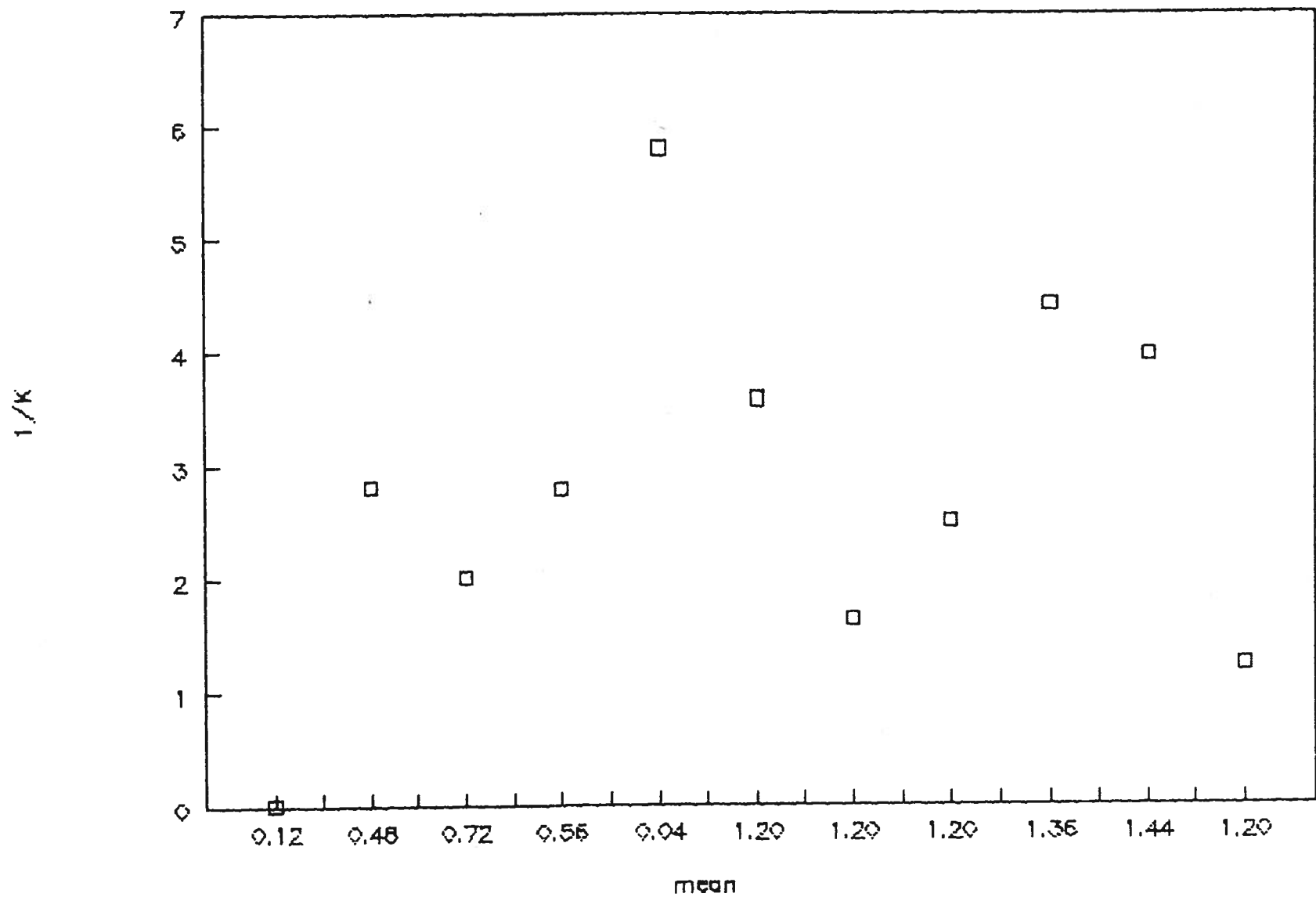


Fig 15 c. Relation of $1/k$ to mean (\bar{x}) for DEM in normal planting (Golden Acre)

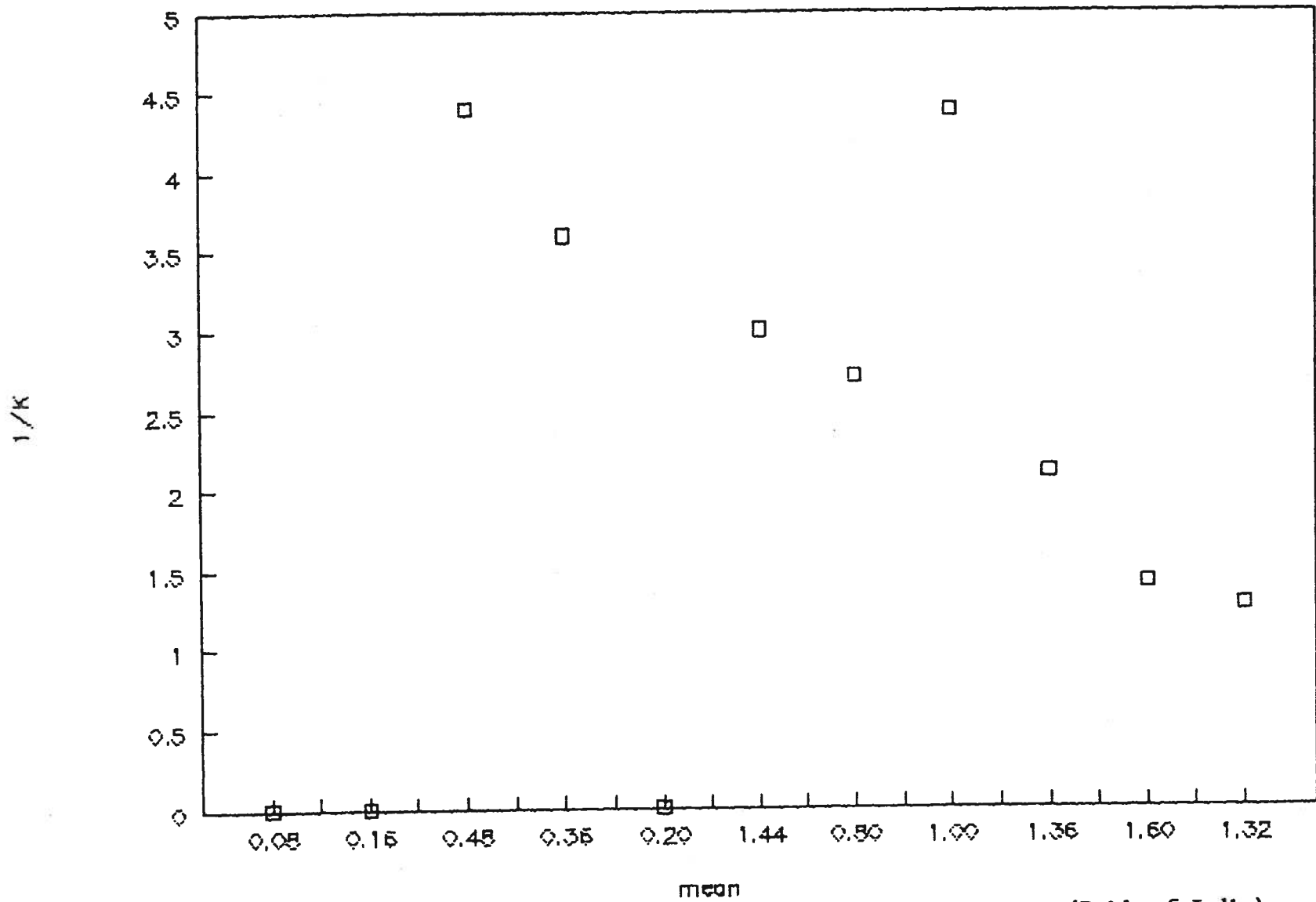


Fig 15 d. Relation of 1/k to mean (\bar{x}) for DBM in normal planting (Pride of India)

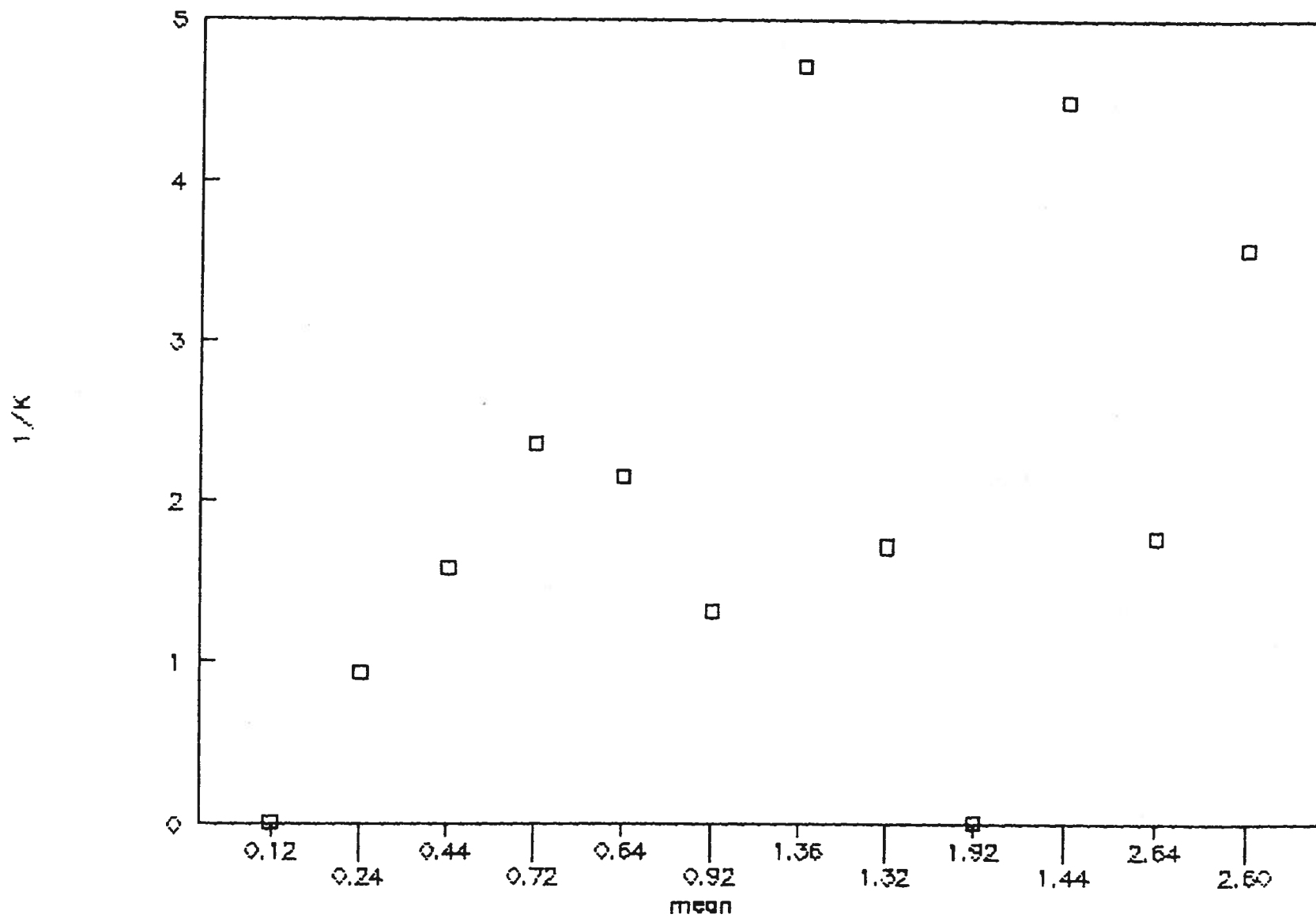


Fig 15 e. Relation of $1/k$ to mean (\bar{x}) for DBM in late planting (Golden Acre)

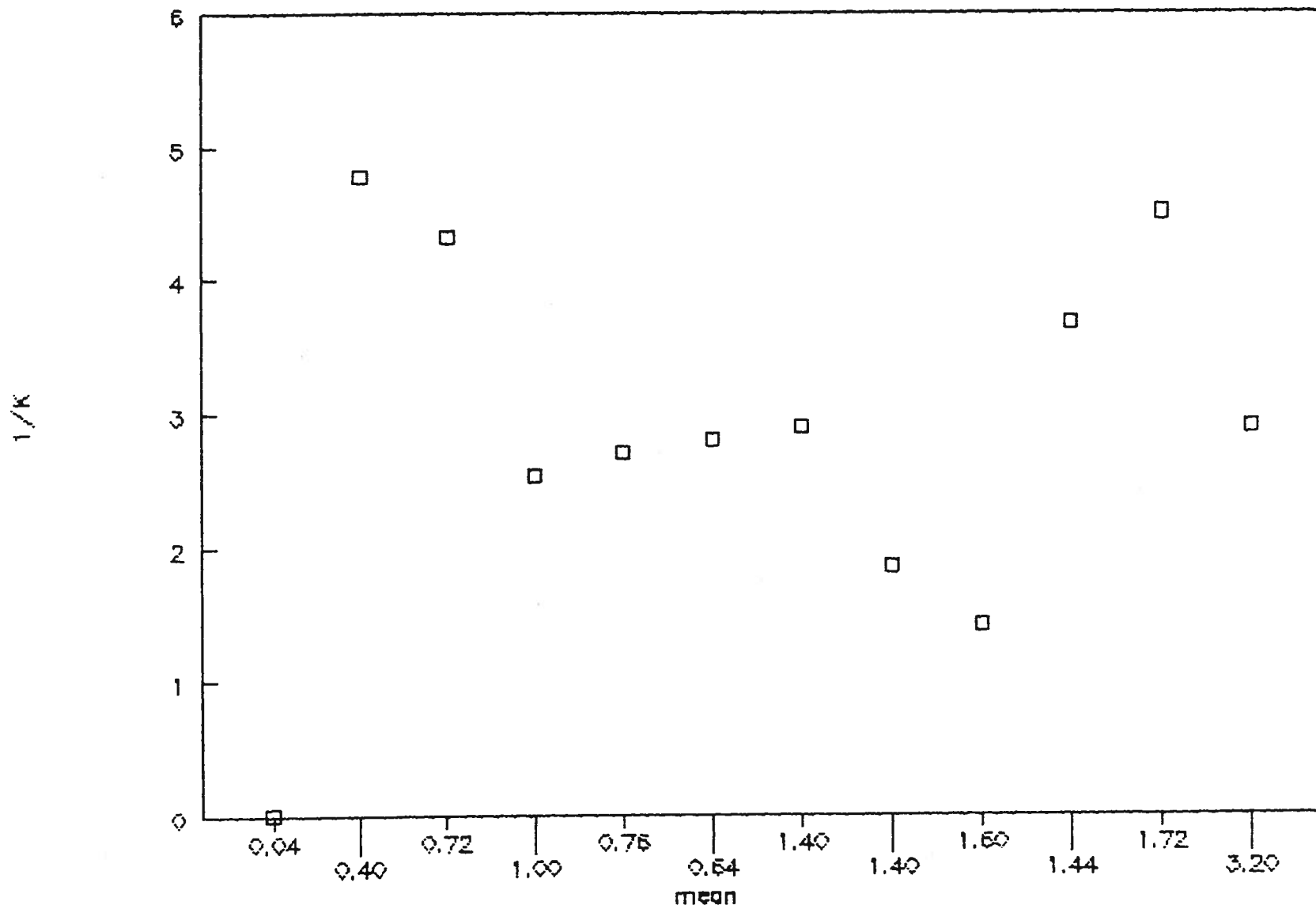


Fig 15 f. Relation of 1/k to mean (\bar{x}) for DBM in late planting (Pride of India)

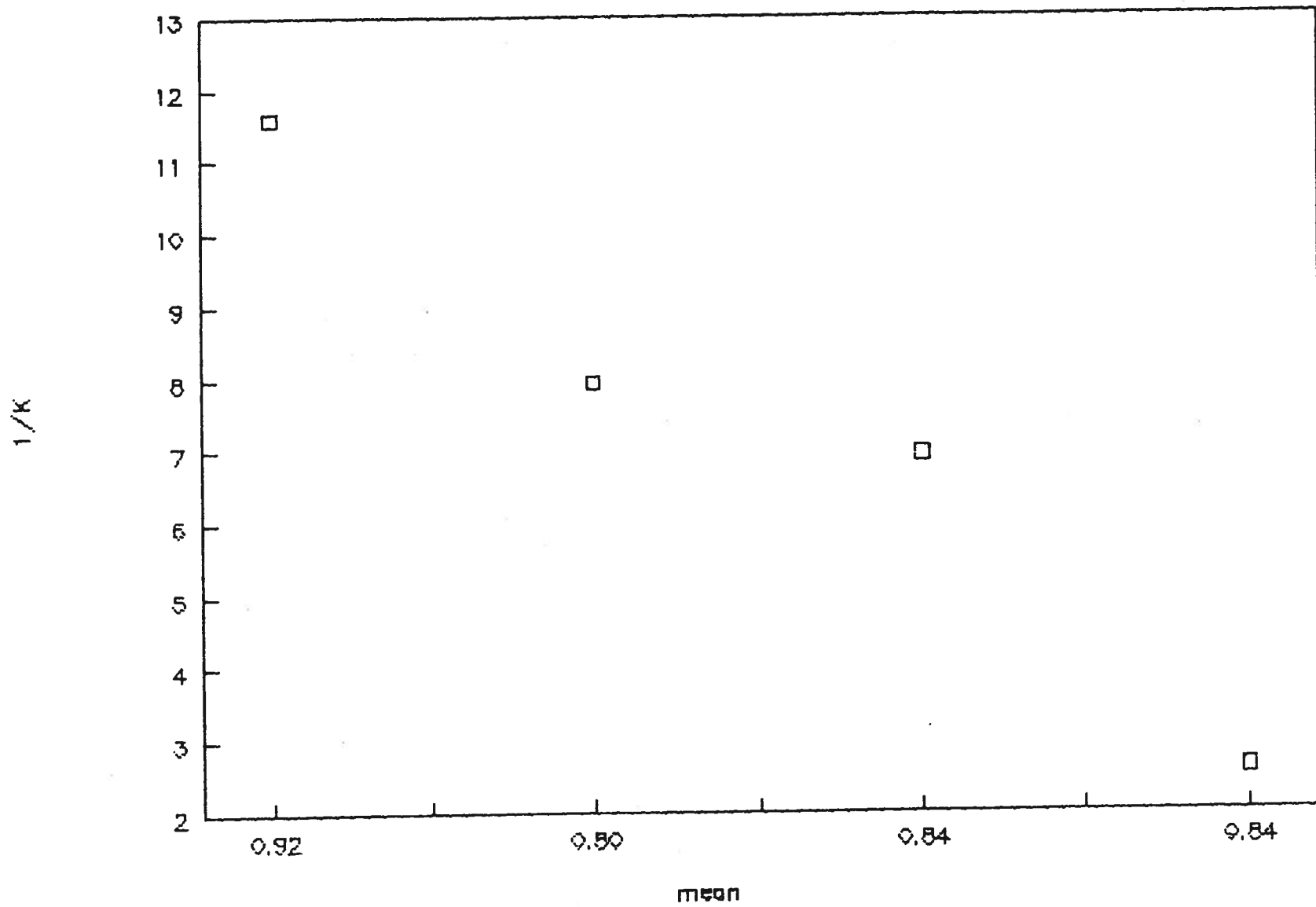


Fig 16 a. Relation of $1/k$ to mean (\bar{x}) for *Heliula* on Golden Acre

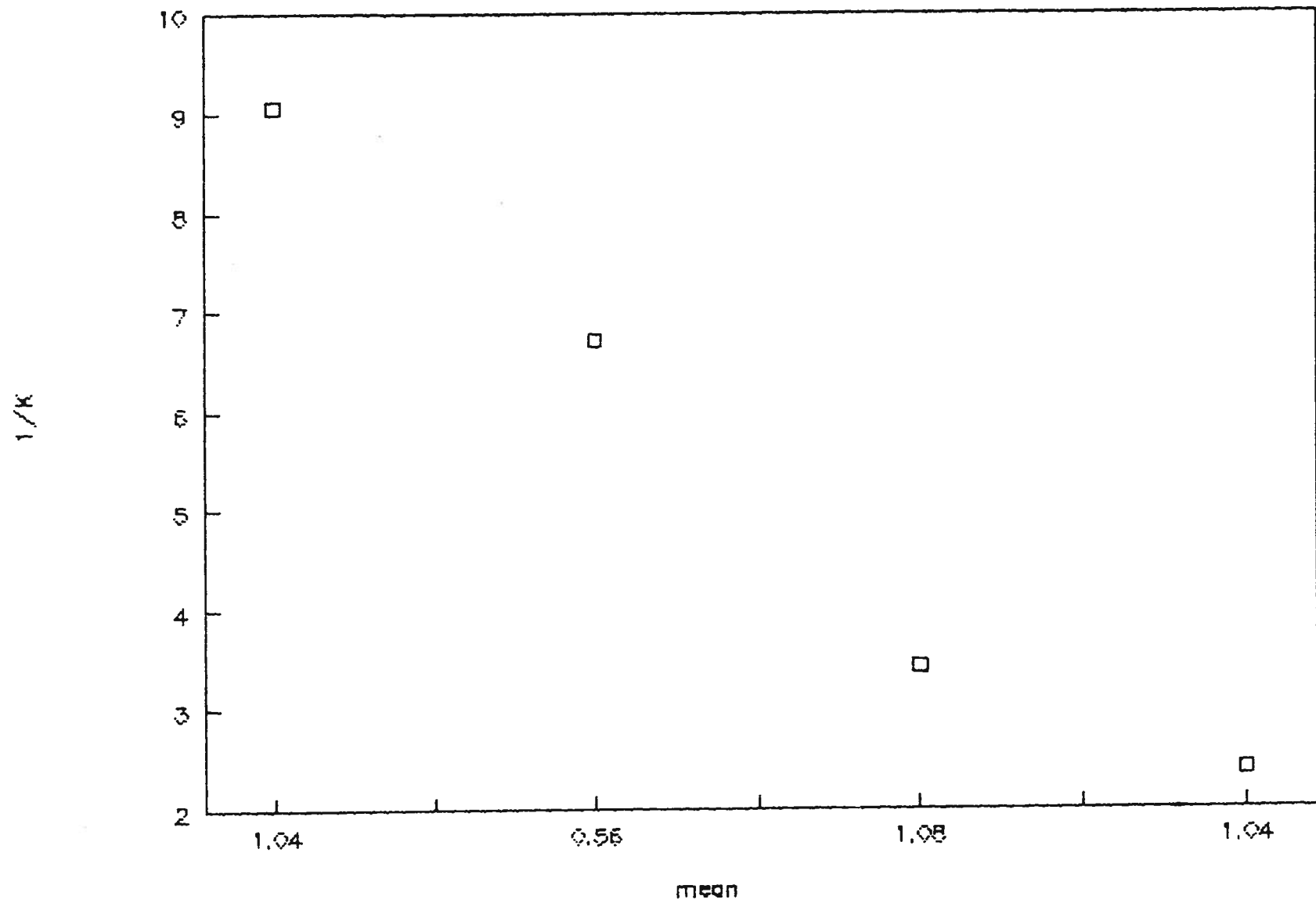


Fig 16 b. Relation of $1/k$ to mean (\bar{x}) for *Hellula* on *Pride of India*

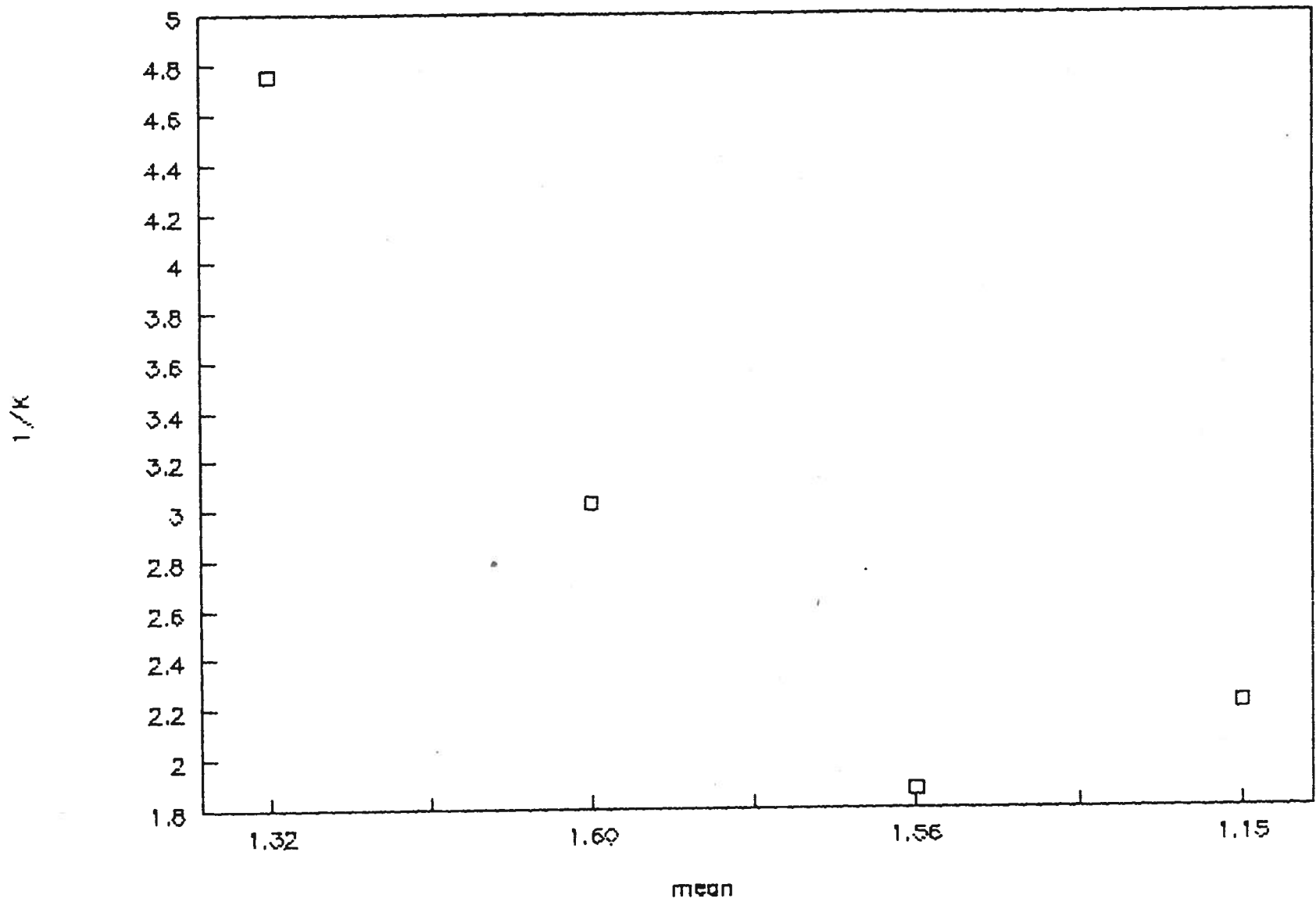


Fig 16 c. Relation of $1/k$ to mean (\bar{x}) for *Crocidolomia* on Golden Acre

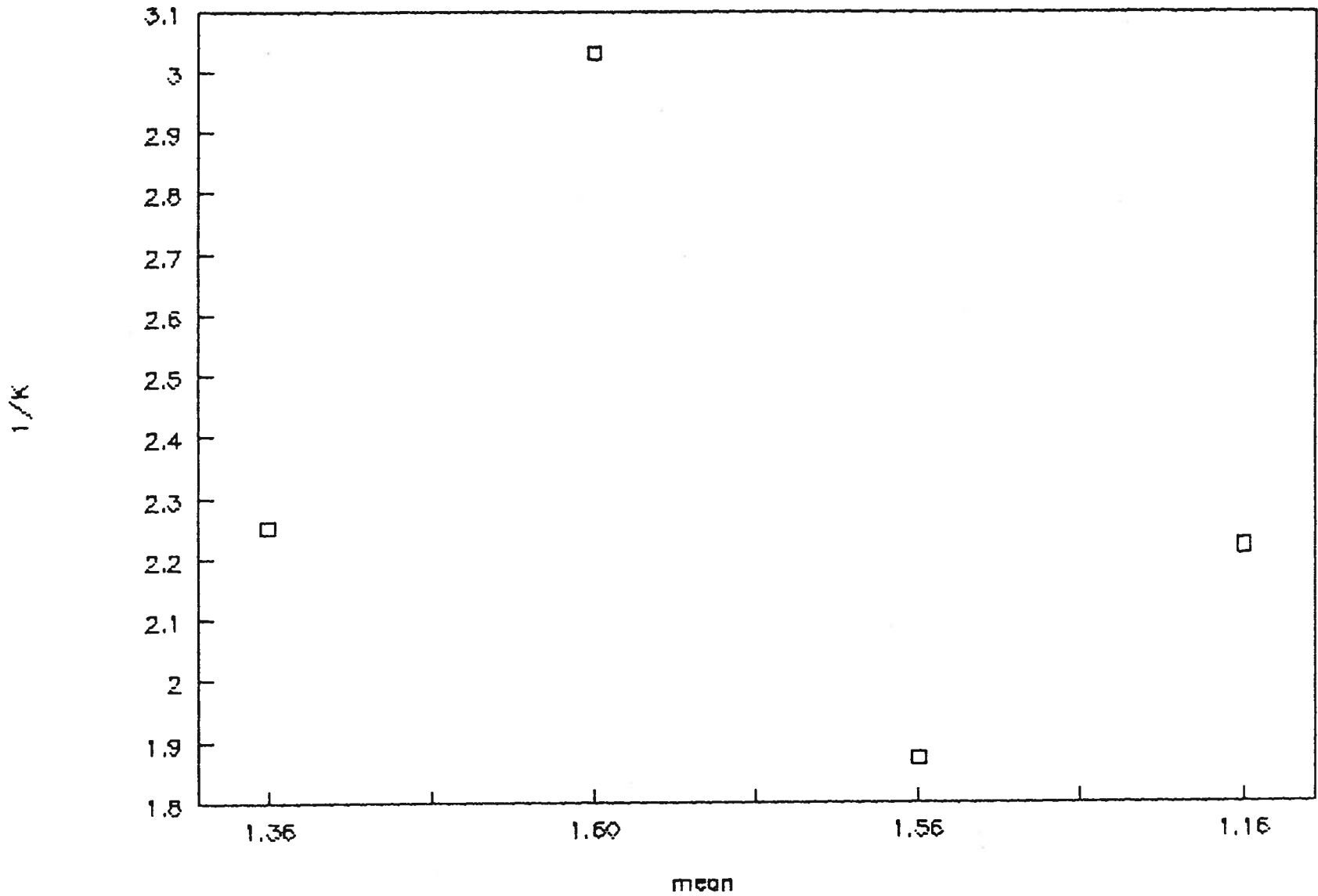


Fig 16 d. Relation of $1/k$ to mean (\bar{x}) for *Crocidolomia* on *Pride of India*

1/K was calculated. The observed value of 'K' and its reciprocal '1/K' for cabbage leaf webber sloped towards contagiousness or aggregation of the population. The estimate of the slope of the regression was to be 1.19 for Golden Acre 5.64 and for Pride of India.

4.4 INDICES OF DISPERSION

The poisson distribution, resulting from random distribution is an useful yardstick by which the actual distributions are compared. As an alternative to random dispersal, the pests are commonly aggregated, so the scatter of the population values tend to be increased by aggregation. To measure the distribution pattern the following indices were tried and are presented pest wise.

4.4.1 Variance to mean ratio of index of dispersion (I)

This test is based on the equality of variance and mean in a Poisson series. The 'I' was computed for all the three plantings and both the varieties. The data obtained indicated that 'I' departed from unity in case of aphids, DBM, Hellula, Crocidolomia as shown in Tables 20 to 22. This indicates that the pests are following a contagious type or aggregated type of distribution.

4.4.1.1 Aphid

In the early planting, the variance to mean ratio ranged from 10.61 to 84.67 in Golden Acre and 6.05 to 113.64 in Pride of

India. As the 'I' departed from unity in all the weeks we can conclude that the aphid distribution in contagious or aggregated type in early plantings. In the normal plantings the 'I' value ranged from 3.85 to 35.46 and 4.54 to 25.34 in case of Golden Acre and Pride of India, respectively, departing from unity indicating an contagious or aggregated type of distribution.

In the late planting, the value of 'I' ranged from 2.67 to 26.96 and 3.02 to 26.93 in Golden Acre and Pride of India respectively. As the values of 'I' departed from unity the distribution is said to be aggregated type (Table 20).

4.4.1.2 DBM

In the early planting, the value of 'I' for DBM ranged in between 3.55 and 1.67 and 15.16 in Golden Acre and Pride of India and showed that the value of I departed from unity in all cases and is said to follow an aggregated type of distribution. The value of 'I' ranged in between 1.88 to 6.15 and 1.81 to 3.32 in case of Golden Acre and Pride of India respectively in normal plantings. All the values of 'I' departed from unity indicating an aggregated type of distribution (Table 21).

In the late planting, the value of 'I' ranged in between 1.53 to 4.04 and 1.04 to 3.21 in case of variety Golden Acre and Pride of India. The values of 'I' departed from unity in all the weeks indicating contagious type of distribution.

Table 20: Estimation of index of dispersion (I) of cabbage aphid on two varieties at three different plantings

S.No.	Age of crop (days)	VAR. GOLDEN ACRE			VAR. PRIDE OF INDIA		
		Early	Normal	Late	Early	Normal	Late
1	7	0.00	3.85	2.67	0.00	4.57	4.38
2	14	10.61	8.39	3.92	6.05	6.80	3.02
3	21	12.11	15.57	17.38	15.72	25.34	15.42
4	28	11.88	19.02	17.69	8.42	17.91	22.07
5	35	5.73	35.46	23.92	89.09	12.89	16.23
6	42	23.29	17.19	26.96	35.94	24.49	26.93
7	49	15.70	14.81	16.37	23.05	12.11	9.91
8	56	21.24	10.03	15.02	22.70	14.93	12.02
9	63	35.85	10.31	5.39	26.71	11.95	6.42
10	70	60.28	11.54	6.64	92.09	9.55	8.32
11	77	84.67	12.08	6.28	113.64	11.74	7.61
12	84	26.52	-	10.53	39.84	-	6.15
13	91	11.54	-	-	7.28	-	-
14	98	58.65	-	-	51.39	-	-

Table 21: Estimation of index of dispersion (I) of DBM on two varieties at three different plantings

S.No.	Age of crop (days)	VAR. GOLDEN ACRE			VAR. PRIDE OF INDIA		
		Early	Normal	Late	Early	Normal	Late
1	7	0.00	*	*	0.00	*	*
2	14	*	2.10	1.14	*	*	2.29
3	21	1.14	2.95	1.53	15.16	3.32	3.07
4	28	0.00	2.10	1.91	0.00	1.82	2.17
5	35	*	6.15	1.94	*	*	2.11
6	42	*	3.47	2.35	*	3.13	2.85
7	49	0.00	2.01	4.04	15.16	2.08	3.21
8	56	2.39	2.71	2.51	*	2.17	2.62
9	63	1.82	2.81	*	2.96	2.57	1.04
10	70	1.35	2.84	2.96	1.59	2.24	2.03
11	77	2.92	1.88	2.77	3.58	1.81	2.93
12	84	3.55	-	3.27	2.35	-	2.84
13	91	2.05	-	-	2.62	-	-
14	98	1.67	-	-	1.89	-	-

* : indicates positive binomial

4.4.1.3 Hellula

The variance to mean ratio ranged from 2.74 to 4.88 and 2.84 to 4.13 in case of variety Golden Acre and Pride of India respectively, which shows that the Hellula population is following an aggregated distribution as the values are departing from unity (Table 22).

4.4.1.4 Crocidolomia

The incidence of this pest was seen in the last one month of early planting. The values of 'I' departed from unity indicating a contagious type of distribution (Table 22).

4.4.2 David and Moore's index

David and Moore's index of dispersion was calculated using the following formula:

$$S^2/\bar{x} - 1$$

and, if the calculated value of David and Moore's index is greater than the table value of maximum regularity (-1) and randomness (0) the dispersion of pests is confirmed as the contagious distribution.

4.4.2.1 Aphid

In all the three plantings, in both the varieties Golden Acre and Pride of India the calculated value of Index was greater than the table value of maximum regularity (-1) and randomness

Table 22: Estimation of index of dispersion (I) of cabbage head borer and cabbage leaf webber on two cabbage varieties

S.No.	Age of crop (days)	<u>HELLULA</u>		<u>CROCIDOLOMIA</u>	
		Golden Acre	Pride of India	Golden Acre	Pride of India
11	77	4.88	4.13	3.64	2.57
12	84	3.65	2.84	1.98	1.98
13	91	3.54	3.54	2.52	2.52
14	98	2.75	2.84	2.28	2.28

(0) which further confirms the contagious distribution (Table 23).

4.4.2.2 DBM

The computed value of David and Moore's index was greater than maximum regularity and randomness in all the three plantings on Golden Acre and Pride of India which confirms aggregated distribution of the pest (Table 24).

4.4.2.3 Hellula and Crocidolomia

Both the pests were noticed in the early planting on both the varieties. The pests followed an aggregated distribution as the calculated value of David and Moore's index were greater than maximum regularity and randomness (Table 25).

4.4.3 Morista's index of dispersion

Morista's index of dispersion (I_G) is independent of the sample mean (\bar{X}) but is influenced by total number of sampling units (n). Morista's index was calculated for every week of experimentation and the results are presented for individual pest.

4.4.3.1 Aphid

The computed Morista's index (I_G) ranged from 0.08 to 4.08; 0.35 to 2.87 and 0.28 to 2.81 in early, normal and late planted crop in Golden Acre. In Pride of India the value ranged from 0.15 to 3.99; 2.28 to 2.90 and 0.15 to 3.08 in early, normal

Table 23: David and Moore's index of dispersion for cabbage aphid

S.No.	Age of crop (days)	Maximum regularity	Random	VAR. GOLDEN ACRE			VAR. PRIDE OF INDIA		
				Early	Normal	Late	Early	Normal	Late
1	7	-1	0	0.00	2.85	1.67	0.00	3.57	3.38
2	14	-1	0	9.61	7.39	2.92	5.05	5.80	2.02
3	21	-1	0	11.11	14.57	16.38	14.72	24.36	14.42
4	28	-1	0	10.88	18.02	16.69	7.42	16.91	21.07
5	35	-1	0	4.73	34.46	22.92	88.09	11.89	15.23
6	42	-1	0	22.29	16.14	25.96	34.94	23.49	25.93
7	49	-1	0	14.70	13.81	15.37	22.05	11.11	8.91
8	56	-1	0	20.24	9.03	14.02	21.70	13.93	11.02
9	63	-1	0	34.85	9.31	4.39	25.71	10.95	5.42
10	70	-1	0	59.28	10.54	5.64	91.09	8.55	7.32
11	77	-1	0	83.67	11.08	5.28	112.64	10.74	6.61
12	84	-1	0	25.52	-	9.53	38.84	-	5.15
13	91	-1	0	10.54	-	-	6.28	-	-
14	98	-1	0	57.65	-	-	50.39	-	-

Table 24: David and Moore's index of dispersion for DBM in different plantings

S.No.	Age of crop (days)	Maxi-mum regu-larity	Ran-dom	VAR. GOLDEN ACRE			VAR. PRIDE OF INDIA		
				Early	Normal	Late	Early	Normal	Late
1	7	-1	0	0.00	*	*	0.00	*	*
2	14	-1	0	*	1.10	0.14	*	*	1.29
3	21	-1	0	0.14	1.95	0.53	14.16	2.32	2.07
4	28	-1	0	0.00	1.10	0.91	0.00	0.82	1.17
5	35	-1	0	*	5.15	0.94	*	*	1.11
6	42	-1	0	*	2.47	1.35	*	2.13	1.85
7	49	-1	0	0.00	1.01	2.04	14.16	1.08	2.21
8	56	-1	0	1.39	1.71	1.51	*	1.17	1.62
9	63	-1	0	0.82	1.81	*	1.96	1.57	1.24
10	70	-1	0	0.35	1.84	1.96	0.59	1.24	1.03
11	77	-1	0	1.92	0.88	1.77	2.58	0.81	1.93
12	84	-1	0	2.55	-	2.27	1.35	-	1.84
13	91	-1	0	1.05	-	-	1.92	-	-
14	98	-1	0	0.67	-	-	0.89	-	-

* : indicates positive binomial

Table 25: David and Moore's index of dispersion for Hellula and Crocidolomia

S.No.	Age of crop (days)	Maximum regularity	Random	<u>HELLULA</u>		<u>CROCIDOLOMIA</u>	
				Golden Acre	Pride of India	Golden Acre	Pride of India
11	77	-1	0	3.88	3.13	2.64	1.57
12	84	-1	0	2.65	1.84	0.98	0.98
13	91	-1	0	2.54	2.54	1.52	1.52
14	98	-1	0	1.75	1.84	1.28	1.28

and late planted crop. The calculated index value were greater than unity for all the weeks of aphid infestation on cabbage crop, thereby confirming the contagious type of distribution of B. brassicae.

The significance of the departure from the unity was tested by the F_0 and is presented in Table 26. Departure from randomness were considered to be significant ($P < 0.05$) when F_0 values was outside the appropriate 5 per cent significance levels of χ^2 for $n-1$ degrees of freedom (Pearson and Hartley, 1966). The calculated value of F_0 was greater than χ^2 for each $n-1$ degrees of freedom in the present investigation except from ninth week and tenth week in Golden Acre and Pride of India respectively in early planting; from sixth week and fifth week in Golden Acre and Pride of India respectively in normal planting and from seventh week in both varieties in late plantings thus, confirming the contagious nature of distribution pattern.

4.4.3.2 DBM

The computed Morista's index ranged from 1.91 to 2.90; 1.69 to 2.62 and 1.21 to 2.50 in early, normal and late plantings of Golden Acre. In variety Pride of India, the values ranged from 2.12 to 2.80; 1.55 to 2.57 and 0.85 to 2.91 in early, normal and late plantings. All the values were greater than unity for all the weeks of DBM infestation, thereby confirming the contagious type of distribution (Table 27).

Table 26: Moristas index of dispersion (I_g), F_0 , df and tabulated χ^2 to measure distribution pattern of cabbage aphid

VAR. GOLDEN ACRE										
S.No.	Age of the crop	Early planting			Normal planting			Late planting		
		I_g	$F_0 = \frac{I_g(\sum x - 1) + (n - \sum x)}{(n - \sum x)}$	Tab. χ^2 24	I_g	$F_0 = \frac{I_g(\sum x - 1) + (n - \sum x)}{(n - \sum x)}$	Tab. χ^2 24	I_g	$F_0 = \frac{I_g(\sum x - 1) + (n - \sum x)}{(n - \sum x)}$	Tab. χ^2 24
1.	7	0.00	0.00	0.00	2.87	72.62	27.44	2.81	54.51	15.38
2.	14	4.08	218.04	27.05	2.16	150.82	40.93	2.49	72.24	39.14
3.	21	3.85	417.30	41.13	1.02	32.72	68.07	1.54	140.12	61.67
4.	28	2.90	125.06	30.20	1.02	34.89	77.07	2.61	417.67	10.12
5.	35	2.88	54.13	4.85	1.64	481.82	72.46	2.30	640.20	66.49
6.	42	3.53	459.73	41.81	0.42	598.08	84.40	1.02	40.18	80.80
7.	49	2.73	438.26	52.00	0.35	641.25	86.25	0.35	548.00	84.69
8.	56	1.30	192.10	74.79	0.40	592.10	84.27	0.28	451.20	76.04
9.	63	0.35	766.40	114.77	0.54	561.96	82.10	0.51	271.35	78.42
10.	70	0.15	2389.66	89.89	0.40	535.11	85.62	0.33	550.83	82.20
11.	77	0.08	2682.64	90.40	0.60	259.60	83.49	0.42	273.70	80.31
12.	84	0.06	2142.42	89.70	-	-	-	0.48	231.32	74.89
13.	91	0.08	806.76	86.23	-	-	-	-	-	-
14.	98	0.33	926.43	84.62	-	-	-	-	-	-

Contd.. Table 26

		VAR. PRIDE OF INDIA								
S.No.	Age of the crop	Early planting			Normal planting			Late planting		
		I_{σ}	$FO = \frac{I_{\sigma}(\Sigma x - 1) + (n - \Sigma x)}$	Tab. χ^2 ----- 24	I_{σ}	$FO = \frac{I_{\sigma}(\Sigma x - 1) + (n - \Sigma x)}$	Tab. χ^2 ----- 24	I_{σ}	$FO = \frac{I_{\sigma}(\Sigma x - 1) + (n - \Sigma x)}$	Tab. χ^2 ----- 24
1.	7	0.00	0.00	0.00	2.78	72.06	29.51	3.08	42.72	0.63
2.	14	3.80	94.00	18.99	1.21	52.18	41.12	2.28	50.88	19.64
3.	21	3.99	284.13	25.77	2.61	532.22	57.28	2.47	360.61	18.94
4.	28	2.89	101.63	9.14	2.90	492.22	49.84	2.07	205.32	56.37
5.	35	3.59	503.79	27.21	0.85	51.70	73.74	1.55	251.70	70.98
6.	42	3.64	889.92	48.90	0.40	710.28	86.78	1.28	236.16	78.84
7.	49	2.16	48.07	61.26	0.51	413.15	80.47	0.40	484.12	81.27
8.	56	1.08	75.16	77.65	0.35	717.65	85.99	0.15	765.03	84.39
9.	63	1.32	239.36	75.15	0.48	450.76	83.98	0.42	295.28	77.09
10.	70	0.79	291.74	82.50	0.42	509.60	86.44	0.40	510.51	83.14
11.	77	0.15	2597.07	89.47	0.28	637.68	85.33	0.15	727.78	84.16
12.	84	0.22	1354.22	87.36	-	-	-	0.48	195.44	69.81
13.	91	0.28	609.60	85.15	-	-	-	-	-	-
14.	98	0.29	1535.69	89.25	-	-	-	-	-	-

Degrees of freedom = 24

Table 27: Morista's index of dispersion (I), F_0 , df and tabulated X^2 to measure distribution pattern of DBM

		VAR. GOLDEN ACRE								
S.No.	Age of the crop	Early planting			Normal planting			Late planting		
		I	$F_0 = \frac{\sum x^2}{n \cdot \sum x} - 1$	Tab. X^2 24	I	$F_0 = \frac{\sum x^2}{n \cdot \sum x} - 1$	Tab. X^2 24	I	$F_0 = \frac{\sum x^2}{n \cdot \sum x} - 1$	Tab. X^2 24
1.	7	0.00	0.00	0.00	*	*	*	*	*	*
2.	14	*	*	*	2.17	32.21	2.94	0.67	*	*
3.	21	0.67	0.33	0.03	1.69	30.24	7.52	2.13	0.33	0.03
4.	28	0.00	0.00	0.00	2.62	38.55	1.61	2.43	29.67	0.94
5.	35	*	*	*	2.35	45.60	9.76	2.37	36.90	30.77
6.	42	*	*	*	2.50	49.50	37.05	2.37	36.30	4.74
7.	49	0.00	0.00	0.00	2.06	38.84	32.57	2.12	40.80	9.86
8.	56	2.88	40.95	11.84	2.28	44.48	34.87	2.50	57.00	5.91
9.	63	2.56	31.80	4.53	1.95	38.25	19.91	1.76	36.16	13.71
10.	70	0.67	0.33	1.77	*	*	*	*	*	*
11.	77	2.90	48.70	18.68	1.75	36.00	25.76	2.24	48.80	27.46
12.	84	2.84	64.48	21.97	1.84	33.24	19.45	1.21	29.12	15.33
13.	91	2.35	36.15	6.66	-	-	-	1.38	33.12	33.93
14.	98	1.90	28.53	5.63	-	-	-	-	-	-

Contd.. Table 27

VAR. PRIDE OF INDIA										
S.No.	Age of the crop	Early planting			Normal planting			Late planting		
		I_{σ}	$F_0 = \frac{I_{\sigma}(\sum x - 1) + (n - \sum x)}{n - \sum x}$	Tab. X2 24	I_{σ}	$F_0 = \frac{I_{\sigma}(\sum x - 1) + (n - \sum x)}{n - \sum x}$	Tab. X2 24	I_{σ}	$F_0 = \frac{I_{\sigma}(\sum x - 1) + (n - \sum x)}{n - \sum x}$	Tab. X2 24
1.	7	0.00	0.00	0.00	*	*	*	*	*	*
2.	14	*	*	*	*	*	*	2.56	33.36	4.11
3.	21	2.31	46.44	8.44	2.36	34.88	2.29	2.62	43.40	9.02
4.	28	0.00	0.00	0.00	2.56	31.80	4.53	2.13	34.20	36.82
5.	35	*	*	*	*	*	*	2.35	36.15	21.60
6.	42	*	*	*	2.57	58.47	33.43	2.43	39.77	2.54
7.	49	0.00	0.00	0.00	2.37	36.30	28.71	2.91	75.48	16.29
8.	56	*	*	*	1.77	30.19	35.07	1.80	36.80	40.94
9.	63	2.39	54.36	19.13	2.02	40.32	35.42	1.62	33.92	38.41
10.	70	2.36	30.80	0.85	1.62	33.92	38.41	1.49	27.95	40.14
11.	77	2.80	63.60	25.74	1.55	28.95	28.23	1.70	35.20	33.92
12.	84	2.35	36.16	21.24	-	-	-	1.19	29.51	23.49
13.	91	2.52	45.00	14.15	-	-	-	-	-	-
14.	98	2.12	34.05	7.62	-	-	-	-	-	-

Degrees of freedom = 24

The significance of departure from the unity was tested by the F_0 and is presented in Tables 27 and 28. Departure from randomness were considered to be significant ($P < 0.05$) when F_0 values was outside the appropriate 5 per cent significance levels X^2 for $n-1$ degrees of freedom (Pearson and Hartley, 1966). The calculated value of F_0 was greater than X^2 for each $n-1$ degrees of freedom in all the weeks, thus confirming the contagious nature of distribution.

4.4.3.3 Hellula

The computed Morista's index value ranged from 2.54 to 3.80 and 2.24 to 3.44 in Golden Acre and Pride of India, respectively. The value departed from unity indicating the contagious nature of distribution. The F_0 was also calculated and the value was greater than X^2 for each $n-1$ degrees of freedom in all the weeks of infestation, thus confirming the contagious nature of distribution (Table 28).

4.4.3.4 Crocidolomia

The Morista's index value ranged from 1.42 to 2.24 and 1.42 to 2.24 in Golden Acre and Pride of India, respectively. The value for all the weeks exceeded unity, indicating the contagious nature of the cabbage leaf webber. The F_0 value was also calculated and the value was greater than X^2 for each $n-1$ degrees of freedom in all the weeks of infestation, thus again confirming the contagious nature of distribution (Table 28).

Table 28: Moristas index of dispersion (I_{δ}), F_0 , df and tabulated χ^2 to measure distribution pattern of Hellula and Crocidolomica

<u>HELLULA</u>							
S.No.	Age of the crop	Golden acre			Pride of India		
		I_{δ}	$F_0 = \frac{I_{\delta}(\sum x - 1) + (n - \sum x)}{(n - \sum x)}$	Tab. χ^2 24	I_{δ}	$F_0 = \frac{I_{\delta}(\sum x - 1) + (n - \sum x)}{(n - \sum x)}$	Tab. χ^2 24
11.	77	3.80	85.60	18.76	3.44	75.24	20.27
12.	84	2.90	52.50	21.38	3.20	43.65	6.56
13.	91	2.90	46.80	32.05	2.89	65.65	3.24
14.	98	2.54	47.10	2.94	2.24	43.84	5.47

Table 28 contd..

		<u>CROCIDOLOMIA</u>					
S.No.	Age of the crop	Golden acre			Pride of India		
		I_{σ}	$F_0 = \frac{\sum x - 1}{(n - \sum x)}$	Tab. χ^2 24	I_{σ}	$F_0 = \frac{\sum x - 1}{(n - \sum x)}$	Tab. χ^2 24
11.	77	2.13	42.13	14.91	1.75	32.25	47.67
12.	84	1.42	29.83	24.04	1.42	23.83	24.04
13.	91	1.78	35.70	28.70	1.78	35.70	28.70
14.	98	2.24	41.36	27.30	2.24	41.36	27.30

4.4.4 Taylor's power law

Taylor's power law was calculated based upon mean (\bar{X}) and variance (S^2) for all the weeks for aphid, DBM, Hellula and Crocidolomia on both the varieties by using the equation.

$$\text{Log } S^2 = \text{Log } a + b \log \bar{X}$$

The Taylor's power law obtained by the above regression are presented in the Table 29 and depicted for aphids in Fig.17.

The value of 'b' for aphids, DBM, Hellula and Crocidolomia in the three plantings on both varieties were more than unity, indicating that the pest population is following an aggregated distribution.

The typical linear relationship between $\log S^2$ and $\log \bar{X}$ predicted by Taylor's power law was observed for all the pests per plant over 25 plants in the experimentation. In general the intercept (a) was different ($P < 0.05$) from 0, indicating that the basic unit of the population was clumped for all the pests. Slope (b) were significantly greater than 1.0 further confirming an aggregated population dispersion.

4.4.5 Lloyd's index of mean crowding

The mean and variance obtained from each week were used to approximate mean crowding (\bar{X}^*) by

$$\bar{X}^* = \bar{X} + [(S^2/\bar{X}) - 1]$$

Table 29 : Taylor's power law regression for different pests of cabbage

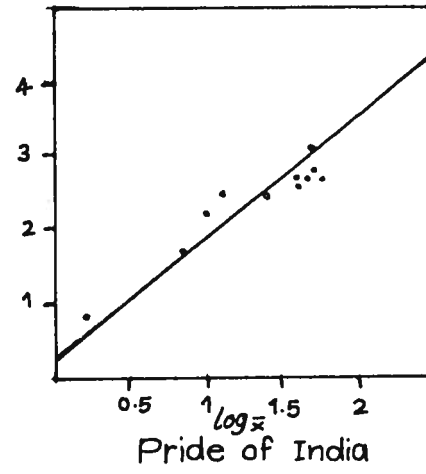
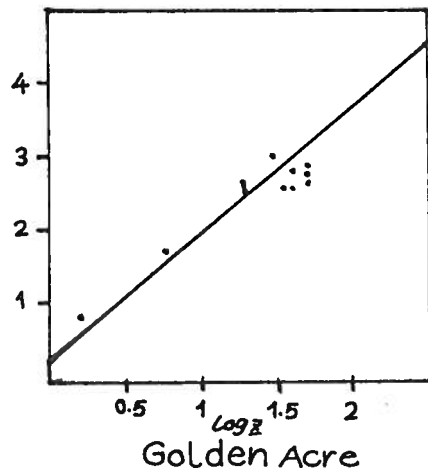
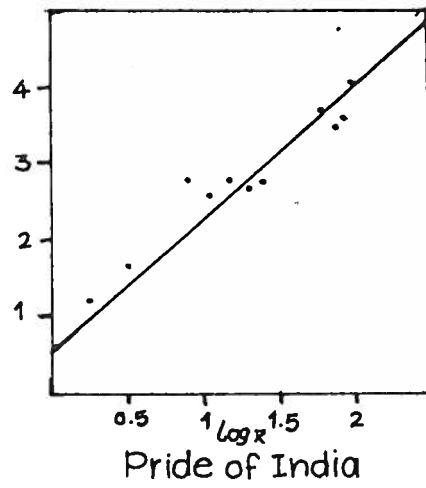
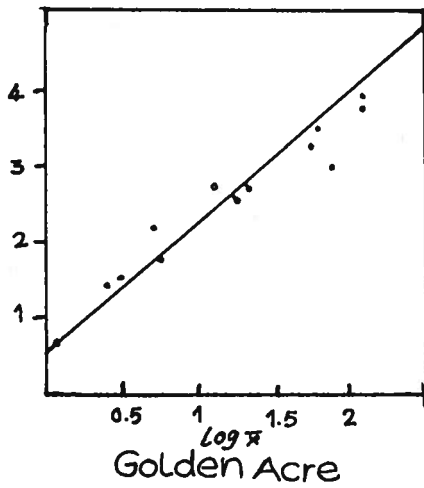
Pest/Planting	Regression of power law	S^2 antilog $a \bar{X}^b$
Var. Golden Acre		
Pest : Aphid		
Early planting	$\log S^2 = 0.6595 + 1.4804 \log \bar{X}$	$S^2 = \text{antilog } 4.5656 \bar{X}^{-1.4804}$
Normal planting	$\log S^2 = 0.5509 + 1.3238 \log \bar{X}$	$S^2 = \text{antilog } 3.5554 \bar{X}^{-1.3238}$
Late planting	$\log S^2 = 8.8956 + 13.49312 \log \bar{X}$	$S^2 = \text{antilog } 786321227.4 \bar{X}^{13.49312}$
Pest : DBM		
Early planting	$\log S^2 = 0.2775 + 1.0841 \log \bar{X}$	$S^2 = \text{antilog } 1.8945 \bar{X}^{-1.0841}$
Normal planting	$\log S^2 = 0.3705 + 1.2687 \log \bar{X}$	$S^2 = \text{antilog } 2.3469 \bar{X}^{-1.2687}$
Late planting	$\log S^2 = 0.3745 + 1.2148 \log \bar{X}$	$S^2 = \text{antilog } 2.3686 \bar{X}^{-1.2148}$
Pest : <u>Hellula</u>		
Early planting	$\log S^2 = 0.6323 + 3.6262 \log \bar{X}$	$S^2 = \text{antilog } 4.2884 \bar{X}^{3.6262}$
Normal planting	-	-
Late planting	-	-
Pest : <u>Crociodomia</u>		
Early planting	$\log S^2 = 0.4053 + 0.4882 \log \bar{X}$	$S^2 = \text{antilog } 2.5427 \bar{X}^{-0.4882}$
Normal planting	-	-
Late planting	-	-

29

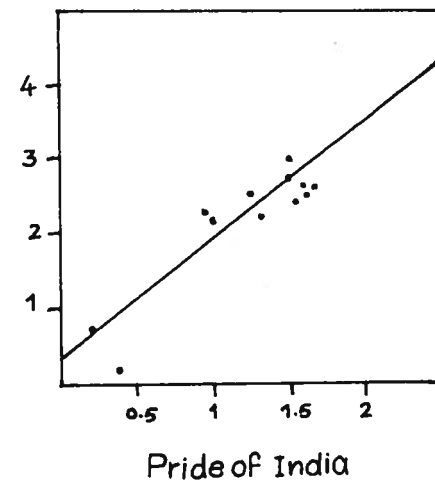
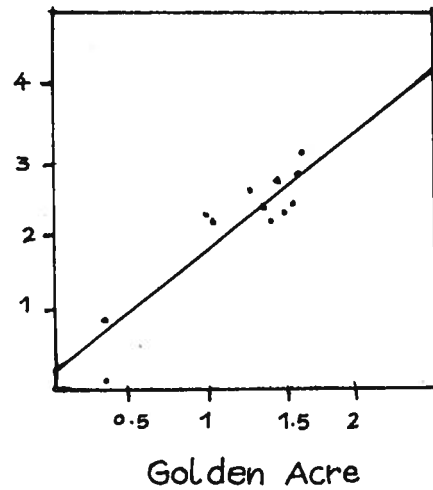
Table 19 contd..

Pest/Planting	Regression of power law	S^2 antilog $a X^b$
Var. Pride of India		
Pest : Aphid		
Early planting	$\log S^2 = 0.9101 + 1.2968 \log X$	$S^2 = \text{antilog } 8.1301 X^{1.2968}$
Normal planting	$\log S^2 = 0.6487 + 1.2451 \log X$	$S^2 = \text{antilog } 4.4534 X^{1.2451}$
Late planting	$\log S^2 = 0.6159 + 1.2263 \log X$	$S^2 = \text{antilog } 4.1295 X^{1.2263}$
Pest : DBM		
Early planting	$\log S^2 = 0.5039 + 1.1490 \log X$	$S^2 = \text{antilog } 3.1908 X^{1.1490}$
Normal planting	$\log S^2 = 0.3141 + 1.0922 \log X$	$S^2 = \text{antilog } 2.0611 X^{1.0922}$
Late planting	$\log S^2 = 0.3121 + 1.0857 \log X$	$S^2 = \text{antilog } 2.0516 X^{1.0857}$
Pest : <u>Hellula</u>		
Early planting	$\log S^2 = 0.4509 + 1.3155 \log X$	$S^2 = \text{antilog } 2.8242 X^{1.3155}$
Normal planting	-	-
Late planting	-	-
Pest : <u>Crocidolomia</u>		
Early planting	$\log S^2 = 0.4053 + 0.4882 \log X$	$S^2 = \text{antilog } 2.5427 X^{0.4882}$
Normal planting	-	-
Late planting	-	-

Log S²



NORMAL PLANTING



LATE PLANTING

Fig-17. Taylor's Power Law for Aphid

The mean crowding index values were calculated for all the three plantings for aphid, DBM, Hellula and Crocidolomia for every week of observation on both the varieties. It was seen that the mean crowding value departed from Poisson series for aphid (Table 30). DBM (Table 31) Hellula and Crocidolomia (Table 32) indicating the aggregated behaviour of the pests.

4.5 INTRA-PLANT DISTRIBUTION OF APHID

Intra-plant distribution was studied for the aphids observed on three leaves from each strata i.e., top, middle and bottom on Golden Acre during the three planting seasons in 1991-92.

4.5.1 Early plantings

In early plantings, the aphid appeared on bottom strata and middle strata at 35 DAT, and it started infesting leaves of top strata at 42 DAT. The mean population of aphids varied between 2.52 to 60.52, 0.32 to 39.84 and 0.48 to 24.48 on top, middle and bottom portion, respectively. The highest mean of aphids were recorded at 77 DAT (60.42 per 3 leaves) in the top strata, 39.84 per 3 leaves in middle strata at 70 DAT and 24.48 per 3 leaves per plant on lower strata leaves.

Students 't' test was done in order to find out which strata harbours more number of aphids. The data was analysed taking two strata into account at a time i.e., top and middle, middle and bottom and top and bottom strata for each of the three

Table 30: Lloyd's index of mean crowding for aphids in different plantings

S.No.	Age of crop (days)	VAR. GOLDEN ACRE			VAR. PRIDE OF INDIA		
		Early	Normal	Late	Early	Normal	Late
1	7	0.00	4.61	2.11	0.00	5.21	3.78
2	14	12.17	13.47	5.32	6.09	13.24	3.62
3	21	16.67	35.61	26.42	18.24	37.18	24.94
4	28	14.08	42.14	26.65	9.34	27.27	30.55
5	35	5.53	63.78	42.52	95.69	38.49	34.03
6	42	29.77	66.90	64.60	48.10	77.41	62.17
7	49	26.82	57.97	54.29	42.85	58.27	50.95
8	56	44.96	60.91	44.18	51.90	64.29	50.22
9	63	92.05	65.63	40.19	54.87	57.15	39.54
10	70	178.00	53.66	45.04	159.09	57.63	51.12
11	77	201.39	49.36	32.64	238.40	52.90	45.69
12	84	46.70	-	33.61	115.92	-	28.19
13	91	123.17	-	-	46.68	-	-
14	98	7.67	-	-	140.91	-	-

Table 31: Lloyd's index on mean crowding for DBM in different plantings

S.No.	Age of crop (days)	VAR. GOLDEN ACRE			VAR. PRIDE OF INDIA		
		Early	Normal	Late	Early	Normal	Late
1	7	0.00	*	*	0.00	*	*
2	14	*	1.58	0.38	*	*	1.69
3	21	0.38	2.67	0.97	14.92	2.80	2.79
4	28	0.00	1.66	1.63	0.00	1.18	2.17
5	35	*	6.43	1.58	*	*	1.87
6	42	*	3.67	2.27	*	3.57	2.49
7	49	0.00	2.21	4.40	14.92	1.88	3.61
8	56	1.95	2.91	2.51	*	2.17	3.02
9	63	1.18	3.17	2.53	3.24	2.93	2.00
10	70	0.63	3.28	3.40	0.95	2.84	2.47
11	77	2.72	2.08	4.41	3.82	2.13	3.65
12	84	3.83	-	4.87	2.19	-	5.04
13	91	1.73	-	-	2.70	-	-
14	98	1.27	-	-	1.65	-	-

* indicates positive binomial

Table 32: Lloyd's index of mean crowding for Hellula and Crocidolomia

S.No.	Age of crop (days)	<u>HELLULA</u>		<u>CROCIDOLOMIA</u>	
		Golden Acre	Pride of India	Golden Acre	Pride of India
11	77	4.80	4.17	3.96	2.93
12	84	3.45	2.40	2.58	2.58
13	91	3.38	3.62	3.08	3.08
14	98	2.59	2.88	2.44	2.44

plantings. It was seen that there was a high significance between all the three strata in the early plantings.

The variance values were greater than mean aphid population on all strata throughout the cropping season indicating over disposition of aphids. From the Table 33 and Fig.18a to 18c it is clearly evident that top strata harboured the maximum aphids.

From the perusal of the data presented in Table 33 and Fig.19, it is clearly seen that 'K' values were intermittently increasing and decreasing on all strata in early plantings. The 'K' values ranged in between 0.12 to 0.26, 0.07 to 0.31 and 0.05 to 0.32 on top, middle and bottom strata, respectively. It is again confirmed that top strata harboured more aphids as dispersion parameter was less when compared to middle and bottom strata.

Relative variation (RV)

The relative variation (RV) was used as a measure of reliability of samples from different strata of the plant and its values are presented in Table 34. The RV values ranged in between 11.83 to 31.26 in top, 11.46 to 59.07 in middle and 0.83 to 46.07 in lower strata, respectively. The information received from RV values of samples from different strata of the plant revealed that mostly lower RV values were recorded for samples drawn from top stratum of the plant. Hence, sampling cabbage aphids on top stratum of plant provided not only the greatest

Table 33: Mean, variance and K_3 in early plantings (intra-plant distribution)

S.No.	Age of crop (days)	Mean (\bar{X})			Variance (S^2)			K_3		
		Top leaf	Middle leaf	Bottom leaf	Top leaf	Middle leaf	Bottom leaf	Top leaf	Middle leaf	Bottom leaf
1	7	-	-	-	-	-	-	-	-	-
2	14	-	-	-	-	-	-	-	-	-
3	21	-	-	-	-	-	-	-	-	-
4	28	-	-	-	-	-	-	-	-	-
5	35	0.00	0.32	0.48	0.00	0.89	4.01	-	0.07	0.05
6	42	2.52	3.80	1.16	15.51	62.00	7.14	0.12	0.14	0.07
7	49	4.08	3.96	4.08	32.83	22.45	26.08	0.15	0.16	0.15
8	56	10.12	8.56	6.04	108.94	63.42	47.87	0.20	0.28	0.27
9	63	28.00	17.08	11.88	852.00	133.33	53.11	0.22	0.29	0.32
10	70	56.52	39.84	22.96	1761.76	848.06	341.71	0.17	0.19	0.24
11	77	60.52	37.40	24.48	2652.09	1182.83	816.09	0.16	0.20	0.25
12	84	38.04	31.16	23.88	1008.71	895.14	551.28	0.20	0.18	0.24
13	91	16.00	12.36	7.80	89.58	50.16	38.58	0.26	0.31	0.32
14	98	28.84	21.84	15.00	728.06	468.97	219.25	0.21	0.25	0.28

- indicates no pest population

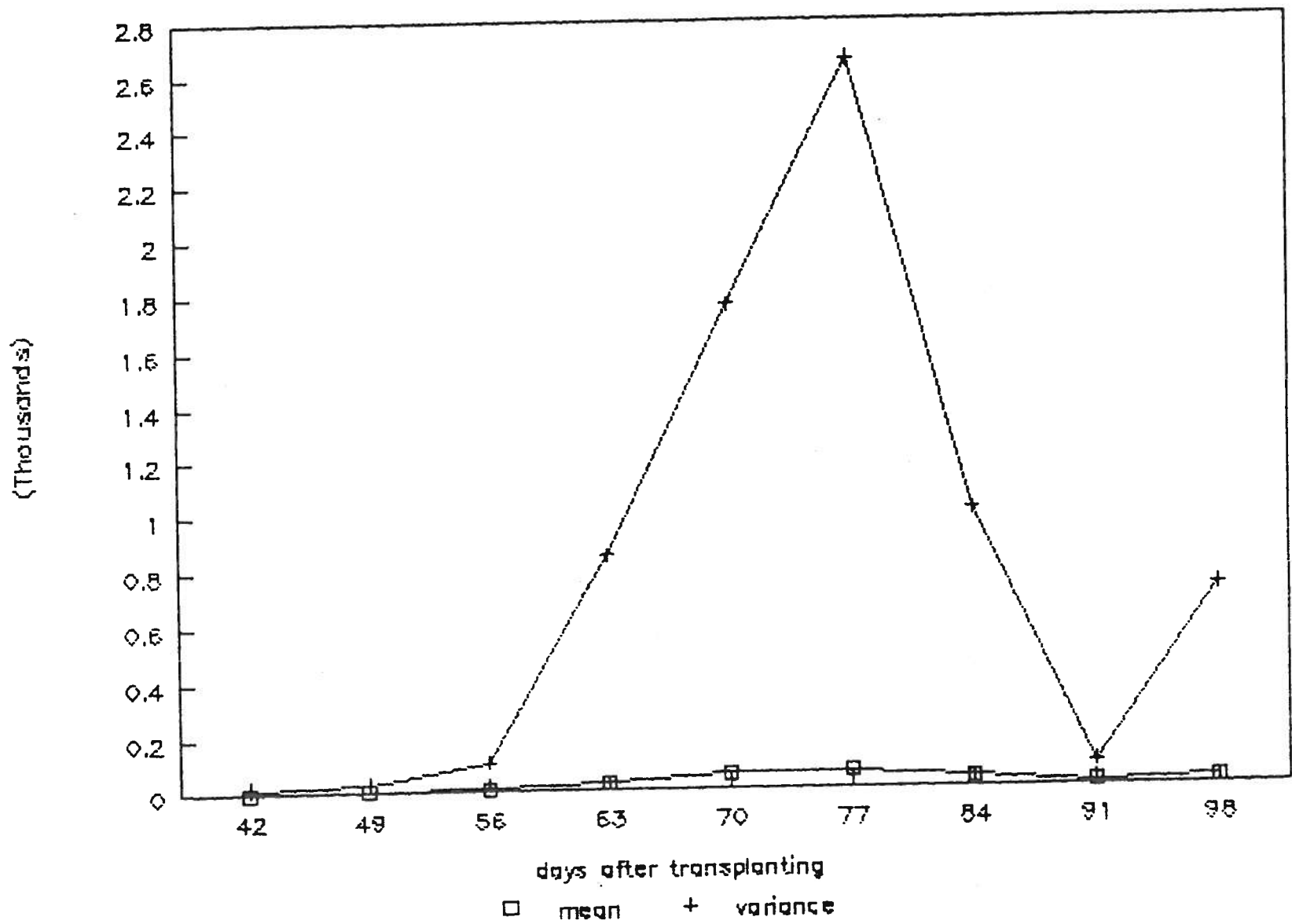
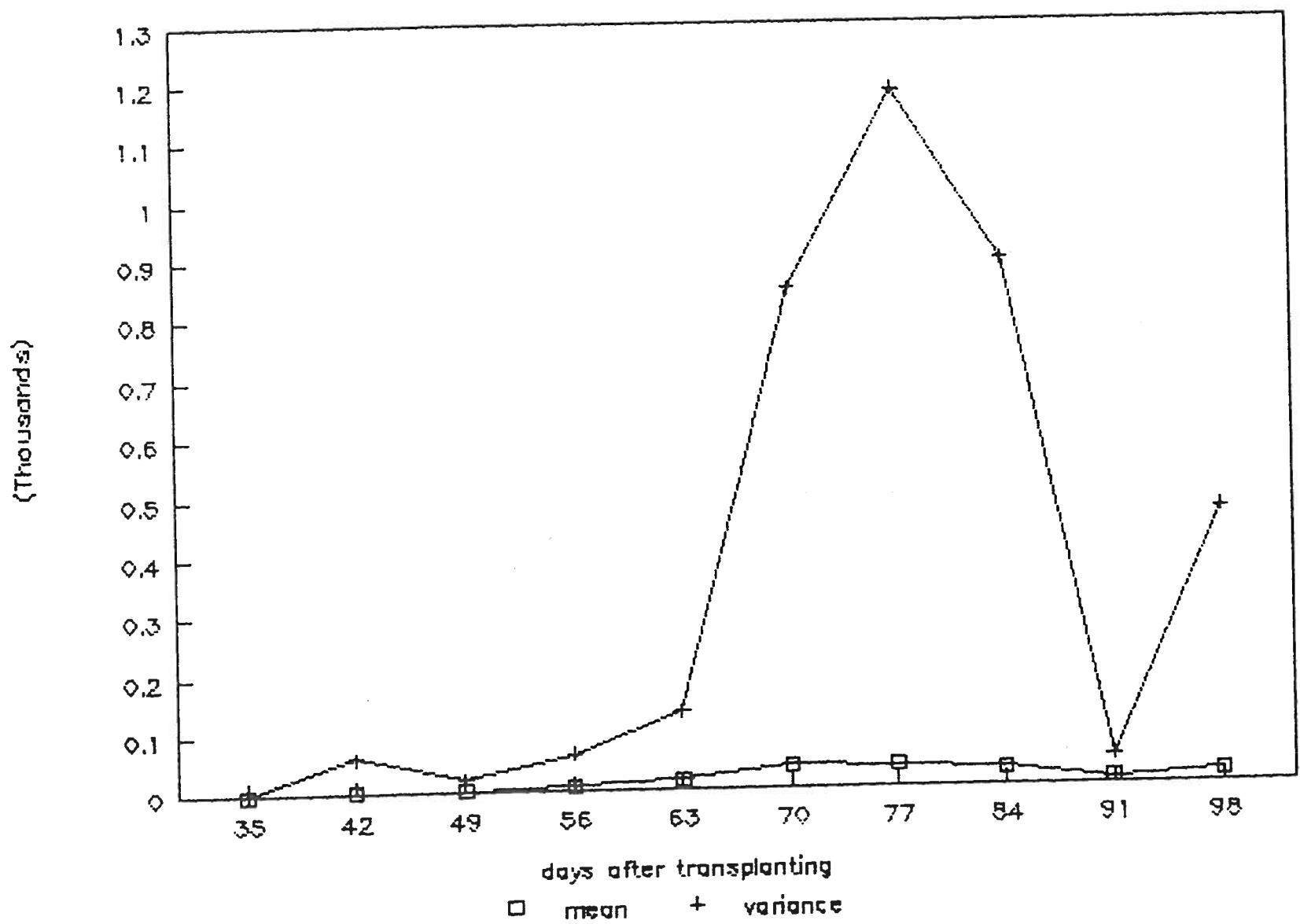


Fig. 19a. Mean and variance of aphid on top stratum on Golden Acre in early planting



196
 Fig 2. Mean and variance of aphid on middle stratum on Golden Acre in early planting

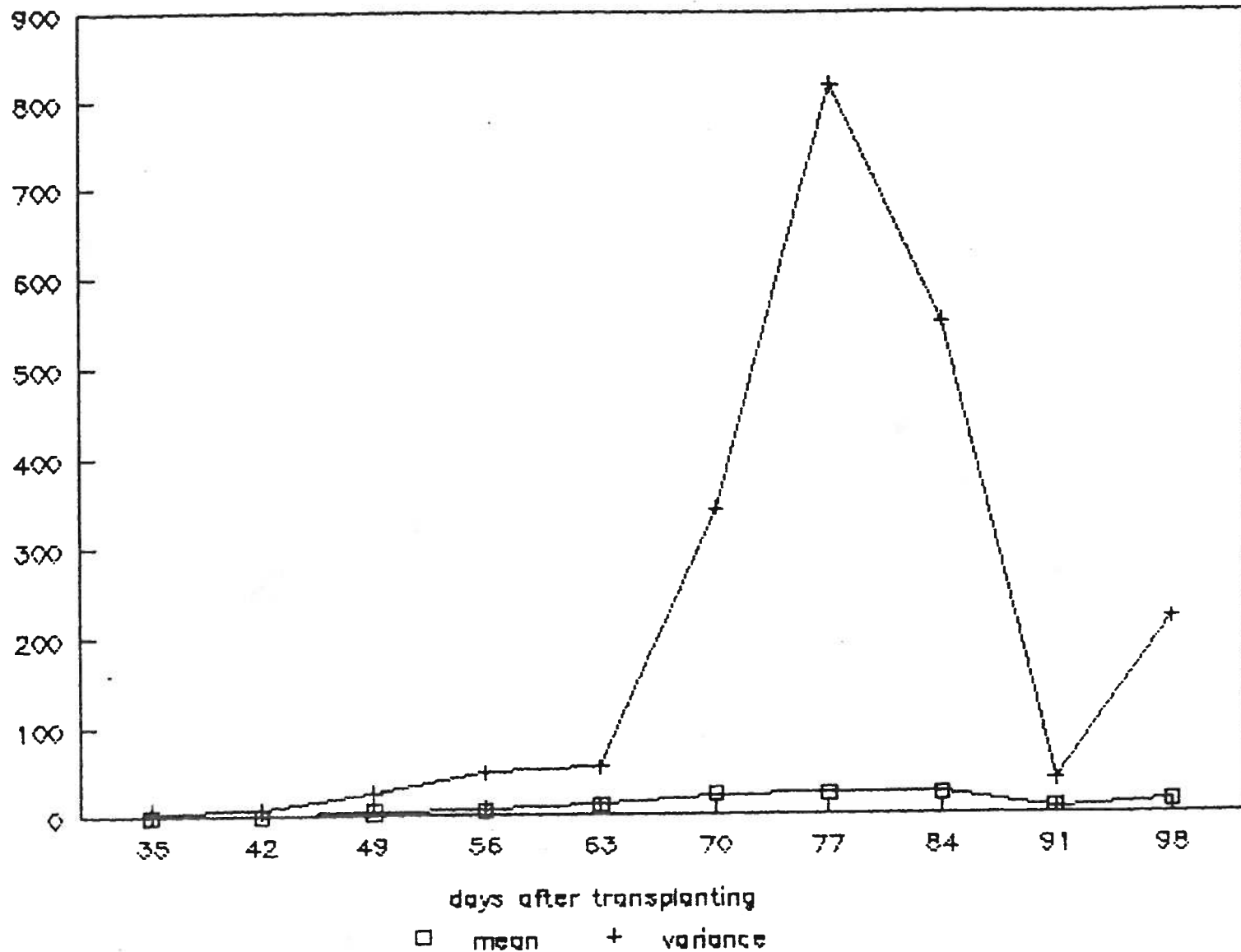


Fig 13c. Mean and variance of aphid on bottom stratum on Golden Acre in early planting

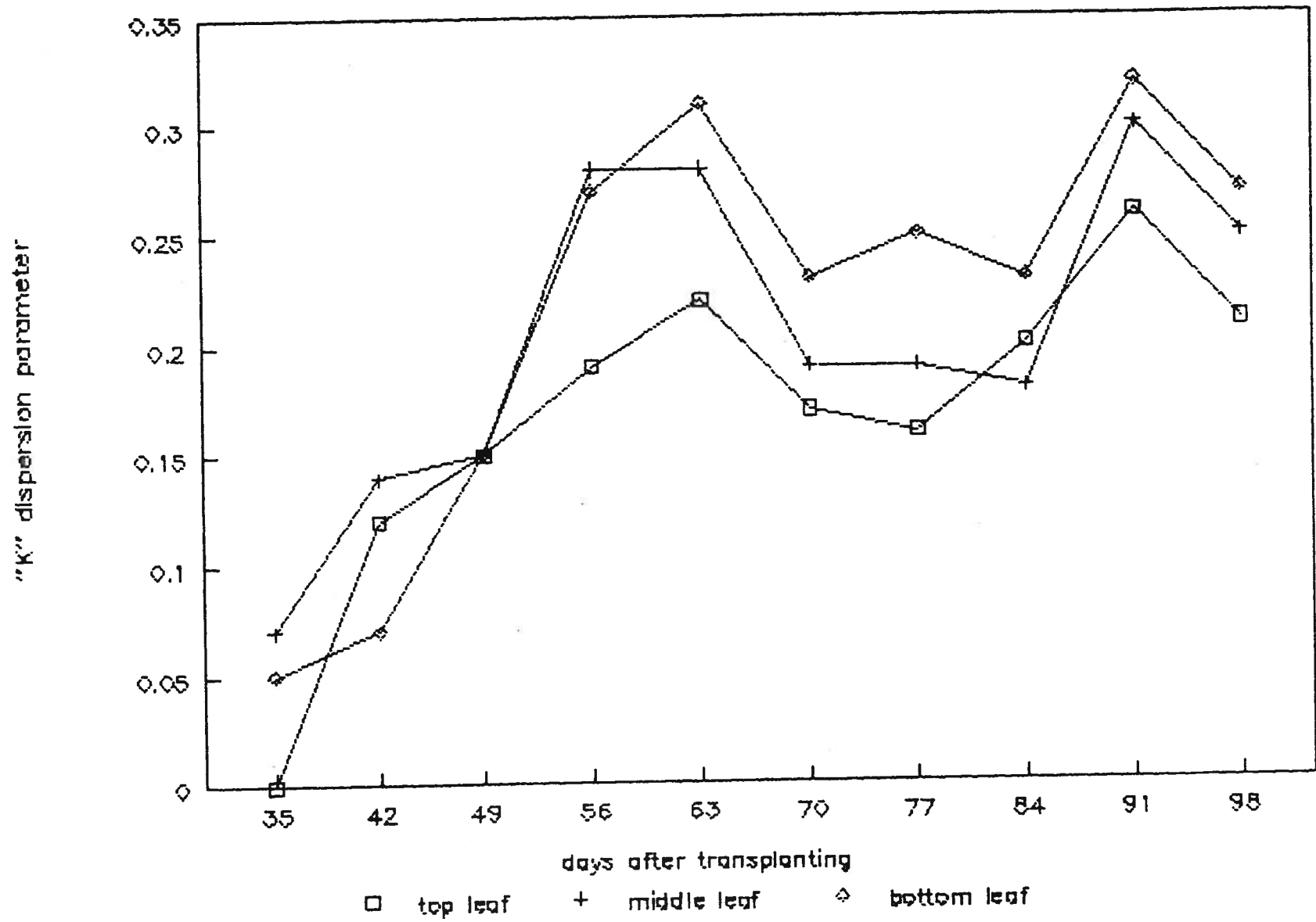


Fig .19 Dispersion parameter 'K' for aphid on different strata in Early Planting

Table 34: Standard Error Mean and Relative Variation of aphids in early plantings

S.No.	Age of crop (days)	SEM			RV		
		Top leaf	Middle leaf	Bottom leaf	Top leaf	Middle leaf	Bottom leaf
1	7	-	-	-	-	-	-
2	14	-	-	-	-	-	-
3	21	-	-	-	-	-	-
4	28	-	-	-	-	-	-
5	35	0.0	0.18	0.80	0.00	59.07	0.83
6	42	3.10	12.40	1.43	31.26	41.44	46.07
7	49	6.57	4.49	5.22	28.09	23.93	25.03
8	56	21.79	12.68	9.57	20.63	18.61	22.91
9	63	170.40	26.67	10.62	20.85	13.52	12.27
10	70	352.35	169.61	68.34	14.85	14.62	16.16
11	77	530.42	236.57	163.22	17.02	18.39	23.34
12	84	201.74	179.03	110.26	16.70	19.20	19.66
13	91	17.92	10.03	7.72	11.83	11.46	15.93
14	98	145.61	93.79	43.85	18.71	19.83	19.74

- indicates no pest population

probability of encountering their highest densities but also the most reasonable and reliable estimate of their density.

Lloyd's index of patchiness

Lloyd's index of patchiness is the ratio of mean crowding to mean density is also very important in deciding the type of distribution. The values of the index ranged from 23.18 to 429.76 for top strata, 4.83 to 248.53 for middle strata and 9.59 to 123.42 for bottom strata respectively. It is evident from the data (Table 35) that these values are more than unity (1) indicating the negative binomial distribution of aphids on all strata of the plant.

Iwao's patchiness regression

Iwao's patchiness regression equation for different strata of the plant are:

(1) For top strata

$$\bar{X}^* = 3.8851 + 1.5677 \bar{X} \quad (R^2 = 0.9756)$$

(2) For middle strata

$$\bar{X}^* = 3.0561 + 1.6046 \bar{X} \quad (R^2 = 0.9364)$$

(3) For bottom strata

$$\bar{X}^* = 1.8523 + 1.8122 \bar{X} \quad (R^2 = 0.9055)$$

From the above equation, the values of α (index of basic contagion) ranged from 1.8523 to 3.8851 for aphid population within top, middle and lower strata of the plant which is greater than 1 and β (density contagiousness coefficient) for above plant

Table 35: Lloyd's index of mean crowding for aphids in three plantings

S.No.	Age of crop (days)	Early planting			Normal planting			Late planting		
		Top leaf	Middle leaf	Bottom leaf	Top leaf	Middle leaf	Bottom leaf	Top leaf	Middle leaf	Bottom leaf
1	7	-	-	-	-	-	-	-	-	-
2	14	-	-	-	-	-	-	-	-	-
3	21	-	-	-	30.55	36.80	44.91	10.98	11.79	38.89
4	28	-	-	-	52.37	25.16	31.45	9.97	21.36	37.73
5	35	0.00	4.83	9.59	73.17	86.44	40.84	42.76	41.52	44.20
6	42	23.18	30.15	17.16	128.73	77.68	50.09	137.78	83.77	43.20
7	49	30.49	29.46	30.39	436.47	62.88	45.03	100.89	62.36	30.99
8	56	61.62	38.90	27.82	138.36	74.15	59.73	58.15	40.31	21.58
9	63	152.55	76.12	49.36	160.99	91.21	60.84	83.73	58.15	19.44
10	70	383.41	248.53	119.27	113.05	70.09	47.05	88.34	46.37	33.55
11	77	429.76	225.53	122.40	106.81	61.59	36.41	58.04	31.06	26.12
12	84	226.26	199.05	123.42	-	-	-	57.33	36.03	186.89
13	91	76.84	52.36	32.10	-	-	-	-	-	-
14	98	164.05	107.82	69.35	-	-	-	-	-	-

strata ranged from 1.5877 to 1.8122 which is approximately equals to 1 confirming that the aphids were distributed as aggregated in all plant stratum.

4.5.2 Normal plantings

In the normal plantings, the incidence of aphid was noticed from 21 DAT on all strata of the plant. The mean aphid population ranged from 6.56 to 27.00, 6.44 to 16.88 and 5.72 to 13.16 on top, middle and bottom strata respectively. The highest mean aphid population was recorded at 63 DAT on both top (27.00 per 3 leaves) and middle leaves (16.88 per 3 leaves). While the highest mean aphid population was recorded at 56 DAT (13.16 per 3 leaves) on bottom leaves. The 't' values obtained were highly significant between all strata. The variance values were greater than mean aphid population on all strata throughout the cropping season indicating an aggregated distribution (Table 36 and Figs. 20a to 20c).

The 'K' values were intermittently increasing and decreasing on all the three strata in the normal plantings as shown in Table 36 and Fig.21. The values of 'K' ranged in between 0.18 to 0.27; 0.15 to 0.46 and 0.22 to 0.30 on top, middle and bottom strata respectively.

Relative variation (RV)

The RV was used as a measure of reliability of samples from different strata of the plant and its values are presented

Table 36: Mean, variance and K_3 in normal plantings (intra-plant distribution)

S.No.	Age of crop (days)	Mean (\bar{X})			Variance (S^2)			K_3		
		Top leaf	Middle leaf	Bottom leaf	Top leaf	Middle leaf	Bottom leaf	Top leaf	Middle leaf	Bottom leaf
1	7	-	-	-	-	-	-	-	-	-
2	14	-	-	-	-	-	-	-	-	-
3	21	6.56	6.44	7.64	36.59	33.59	60.16	0.27	0.21	0.21
4	28	10.64	7.88	5.72	68.07	58.44	72.88	0.26	0.46	0.22
5	35	11.12	11.32	7.32	261.07	206.81	63.14	0.18	0.15	0.22
6	42	23.04	16.00	11.68	199.04	85.17	46.23	0.22	0.26	0.30
7	49	22.48	12.08	10.40	192.76	49.74	45.75	0.20	0.25	0.30
8	56	23.88	14.84	13.16	161.61	34.56	50.31	0.21	0.25	0.28
9	63	27.00	16.88	12.44	176.08	56.61	31.76	0.20	0.23	0.26
10	70	19.52	13.48	10.12	123.01	47.84	43.86	0.21	0.24	0.27
11	77	17.92	12.12	8.12	114.41	48.53	34.19	0.20	0.25	0.29

- indicates no pest population

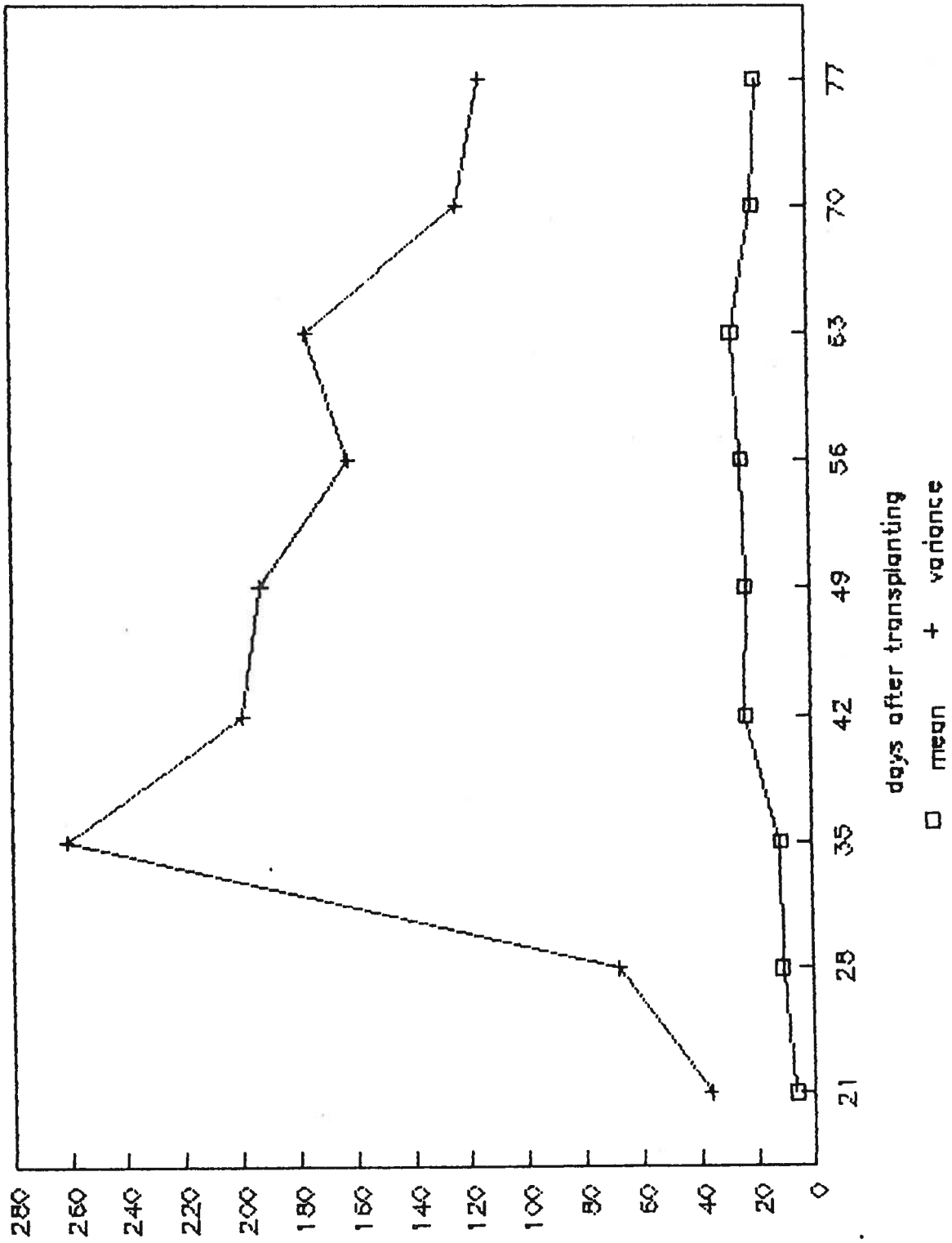
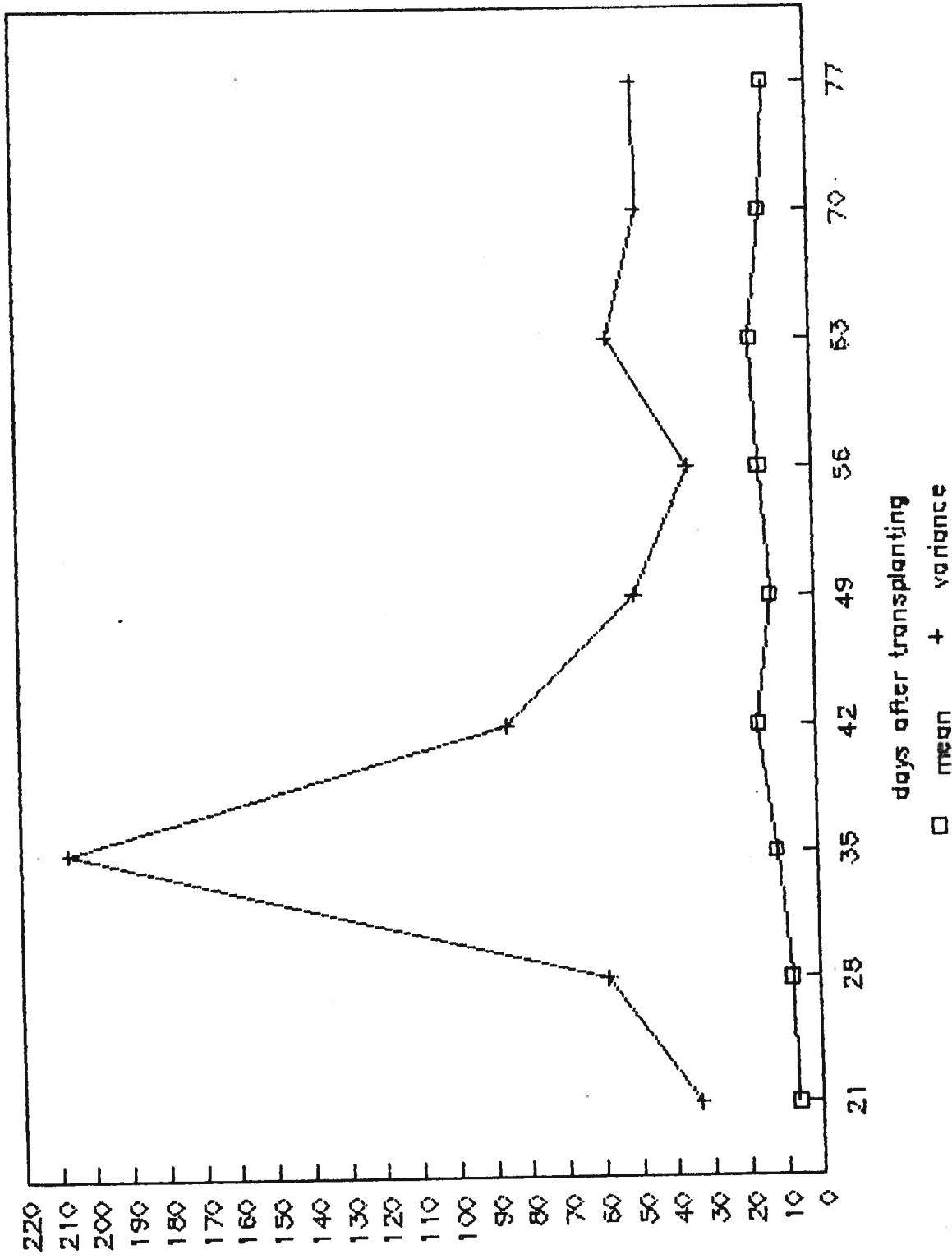


Fig. 20. Mean and variance of aphid on top stratum on Golden Acre in Normal planting



20b . Mean and variance of aphid on middle stratum on Golden Acre in Normal Planting

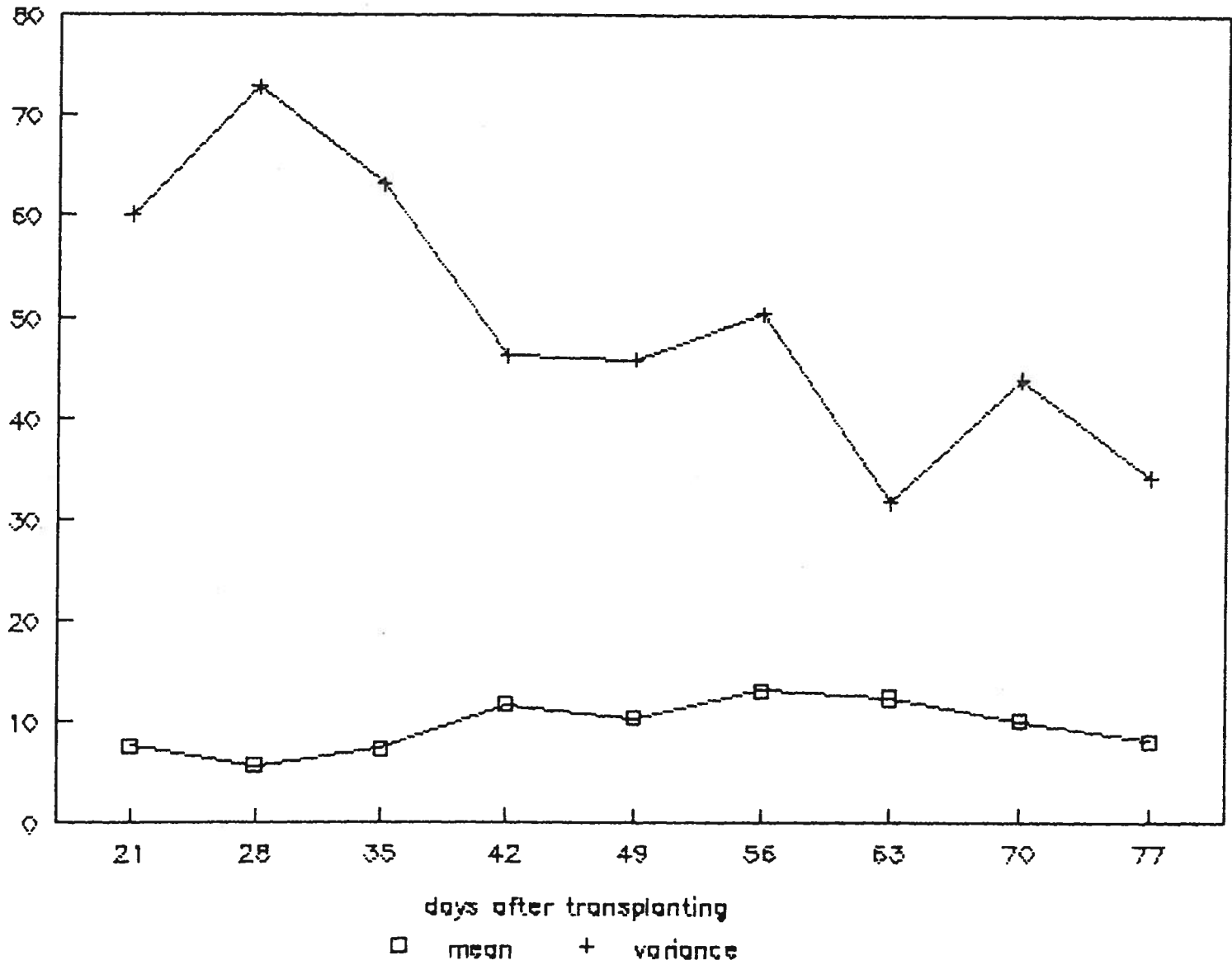


Fig 20c-Mean and variance of aphid on bottom stratum on Golden Acre in Normal Planting

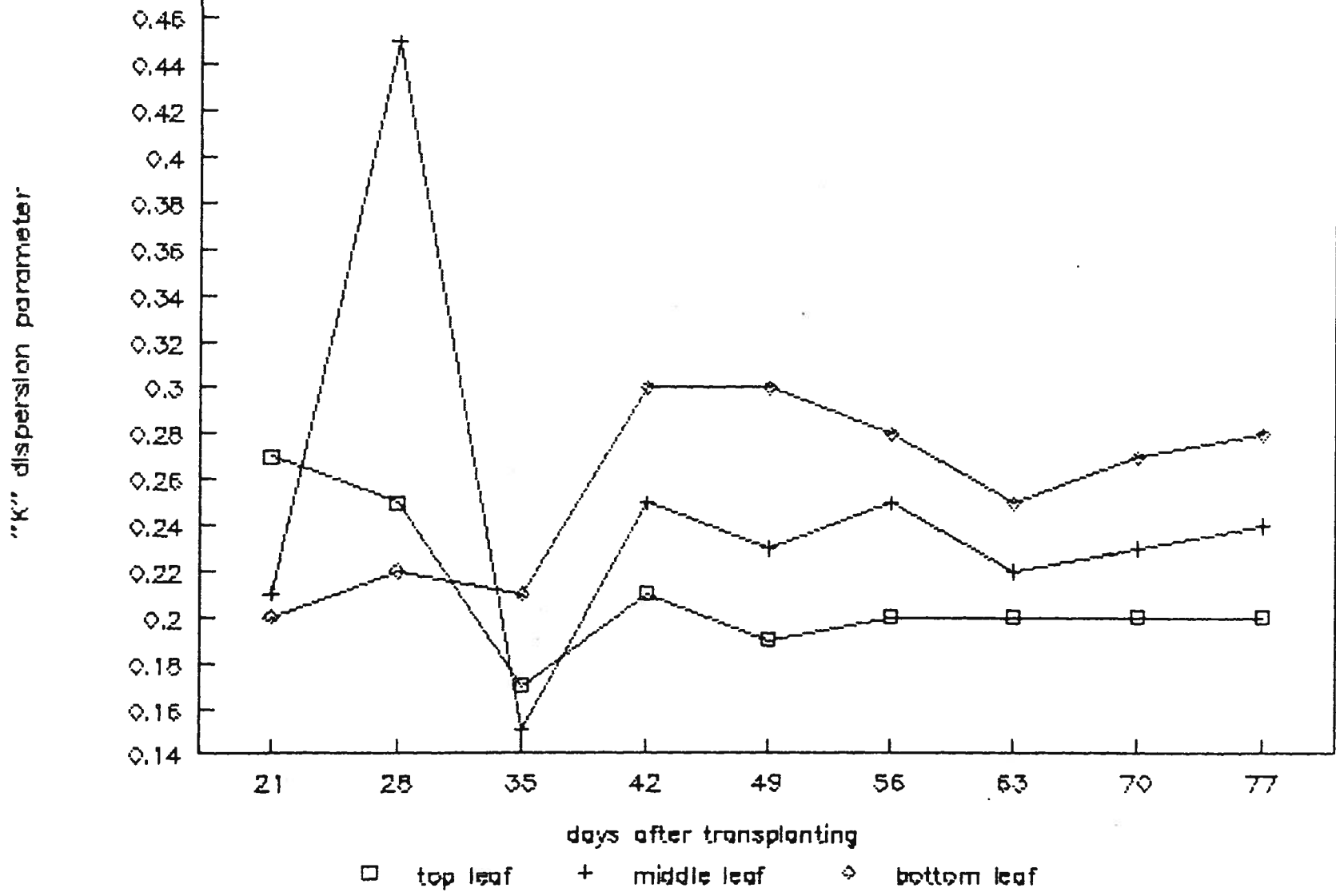


Fig 21 Dispersion parameter 'K' for aphid on different strata in Normal Planting

D. 41355
20.4.93

in Table 37. The values of RV ranged from 9.83 to 29.06; 7.92 to 25.41 and 9.06 to 29.85 on top, middle and bottom strata of the plant.

Lloyd's index of patchiness

The values of Lloyd's index of patchiness ranged from 30.55 to 160.99; 25.16 to 91.21 and 31.45 to 60.84 on top, middle and bottom strata. It is evident from the data (Table 35) that these values are greater than unity (1) indicating the negative binomial distribution.

Iwao's patchiness regression

Iwao's patchiness regression equation for different strata of the plant in normal planting are:

(1) For top strata

$$\bar{X}^* = 4.0431 + 1.1552 \bar{X} \quad (R^2 = 0.7901)$$

(2) For middle strata

$$\bar{X}^* = 2.2972 + 1.1739 \bar{X} \quad (R^2 = 0.6873)$$

(3) For bottom strata

$$\bar{X}^* = 3.2196 + 1.6936 \bar{X} \quad (R^2 = 0.6674)$$

From the above equations, the values of α (index of basic contagion) ranged from 2.2972 to 4.0431 for aphid population which is greater than one and β (density contagiousness coefficient) ranged from 1.1552 to 1.6936 which is greater than 1 confirming that the aphids were distributed on negative binomial in all plant strata.

APR 11 1993

Table 37: Standard Error Mean and Relative Variation of aphids in normal plantings

S.No.	Age of crop (days)	SEM			RV		
		Top leaf	Middle leaf	Bottom leaf	Top leaf	Middle leaf	Bottom leaf
1	7	-	-	-	-	-	-
2	14	-	-	-	-	-	-
3	21	7.32	6.72	12.03	18.44	18.00	20.30
4	28	13.61	11.69	14.58	15.51	19.40	29.85
5	35	52.21	41.36	12.63	29.06	25.41	21.71
6	42	39.81	17.03	9.25	12.25	11.54	11.64
7	49	38.55	6.91	10.06	12.35	11.68	13.01
8	56	53.32	6.91	10.06	10.65	7.92	10.78
9	63	35.22	11.32	6.35	9.83	8.91	9.06
10	70	24.60	9.57	8.77	11.38	10.26	13.09
11	77	22.88	8.09	6.84	11.94	11.50	14.40

4.5.3 Late planting

The incidence of aphid in the late planting was noticed from 21 DAT. The mean aphid population ranged from 2.64 to 20.20; 3.32 to 13.64 and 3.24 to 29.76 on top, middle and bottom leaves respectively. The highest mean aphid population was recorded at 42 DAT on both top (20.20 per 3 leaves) and middle strata (13.64 per 3 leaves) and on the bottom strata it was noticed at 84 DAT (29.76 per 3 leaves). The variance in all the cases were greater than the values of mean thus indicating an aggregated nature of distribution (Table 38 and Figs. 22a to 22c). The 't' test revealed the significant difference between top and middle strata only.

The 'K' values showed an intermittent increasing and decreasing trend throughout the cropping season on all the three strata. The values of 'K' ranged in between 0.17 to 0.47; 0.17 to 0.39 and 0.09 to 0.60 on top, middle and bottom strata respectively (Fig. 23).

Relative variation (RV)

The values of relative variation, used as a measure of reliability of samples from different strata of the plant, ranged from 9.14 to 22.99; 9.34 to 28.16 and 12.39 to 35.34 on top, middle and bottom strata of the plant (Table 39).

Table 38: Mean, variance and K_3 in late plantings of cabbage aphid (intra-plant distribution)

S.No.	Age of crop (days)	Mean (\bar{X})			Variance (S^2)			K_3		
		Top leaf	Middle leaf	Bottom leaf	Top leaf	Middle leaf	Bottom leaf	Top leaf	Middle leaf	Bottom leaf
1	7	-	-	-	-	-	-	-	-	-
2	14	-	-	-	-	-	-	-	-	-
3	21	3.48	3.32	3.24	15.84	19.89	32.77	0.46	0.39	0.09
4	28	2.64	3.48	3.84	8.24	24.01	35.56	0.36	0.19	0.11
5	35	6.80	5.92	7.32	61.08	65.24	70.27	0.19	0.17	0.20
6	42	20.20	13.64	7.32	277.92	123.66	45.31	0.17	0.19	0.20
7	49	18.20	12.84	7.88	153.92	84.47	35.61	0.22	0.26	0.34
8	56	12.88	10.76	6.52	97.28	99.61	32.43	0.28	0.36	0.43
9	63	16.88	12.12	7.32	59.53	28.69	20.56	0.25	0.26	0.60
10	70	17.68	12.36	9.36	46.73	33.32	35.32	0.25	0.36	0.39
11	77	12.88	8.36	6.12	50.61	23.99	20.69	0.29	0.37	0.31
12	84	11.92	6.88	29.76	59.99	36.44	490.11	0.26	0.24	0.19

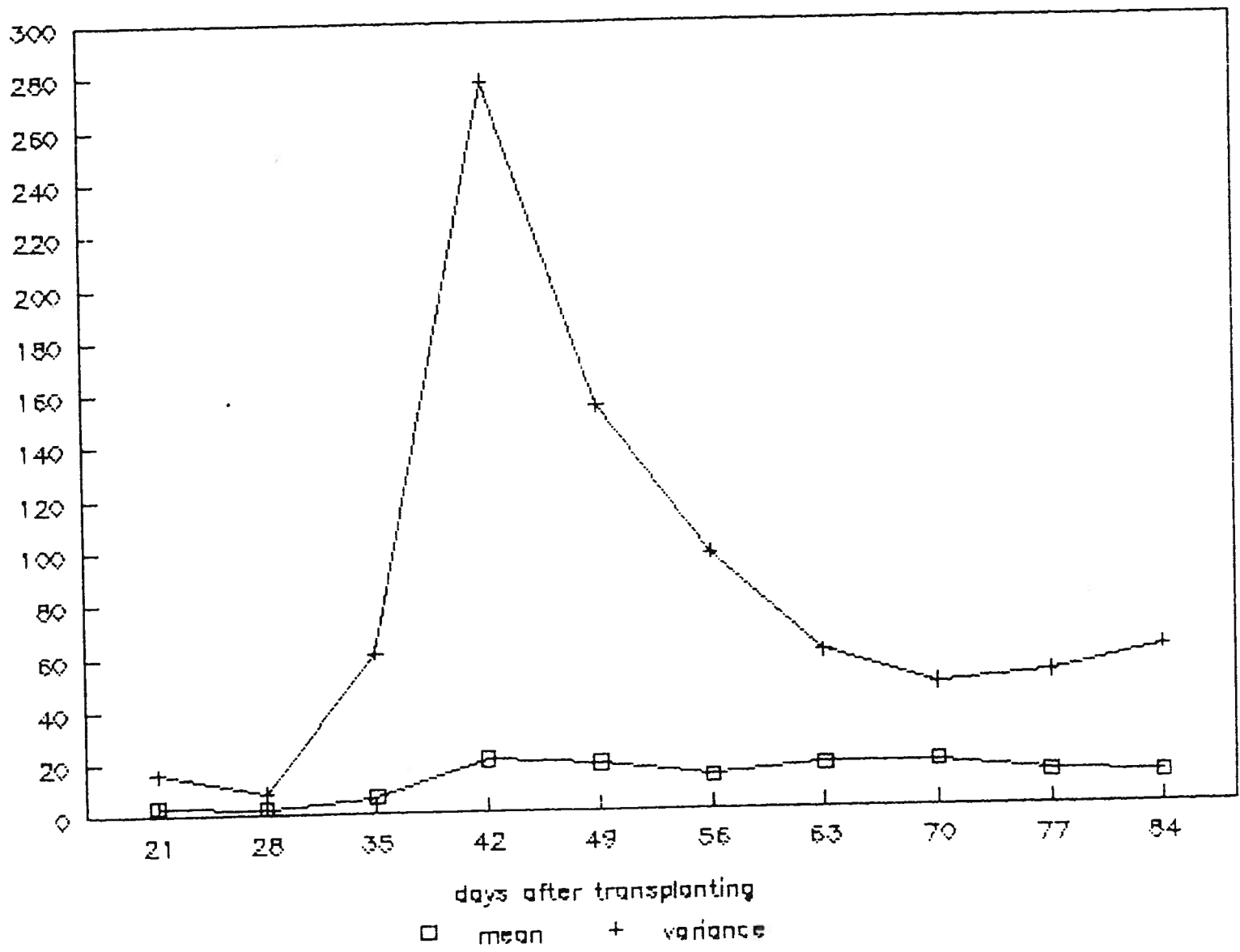


Fig 2.2a. Mean and variance of aphid on top stratum on Golden Acre in late planting

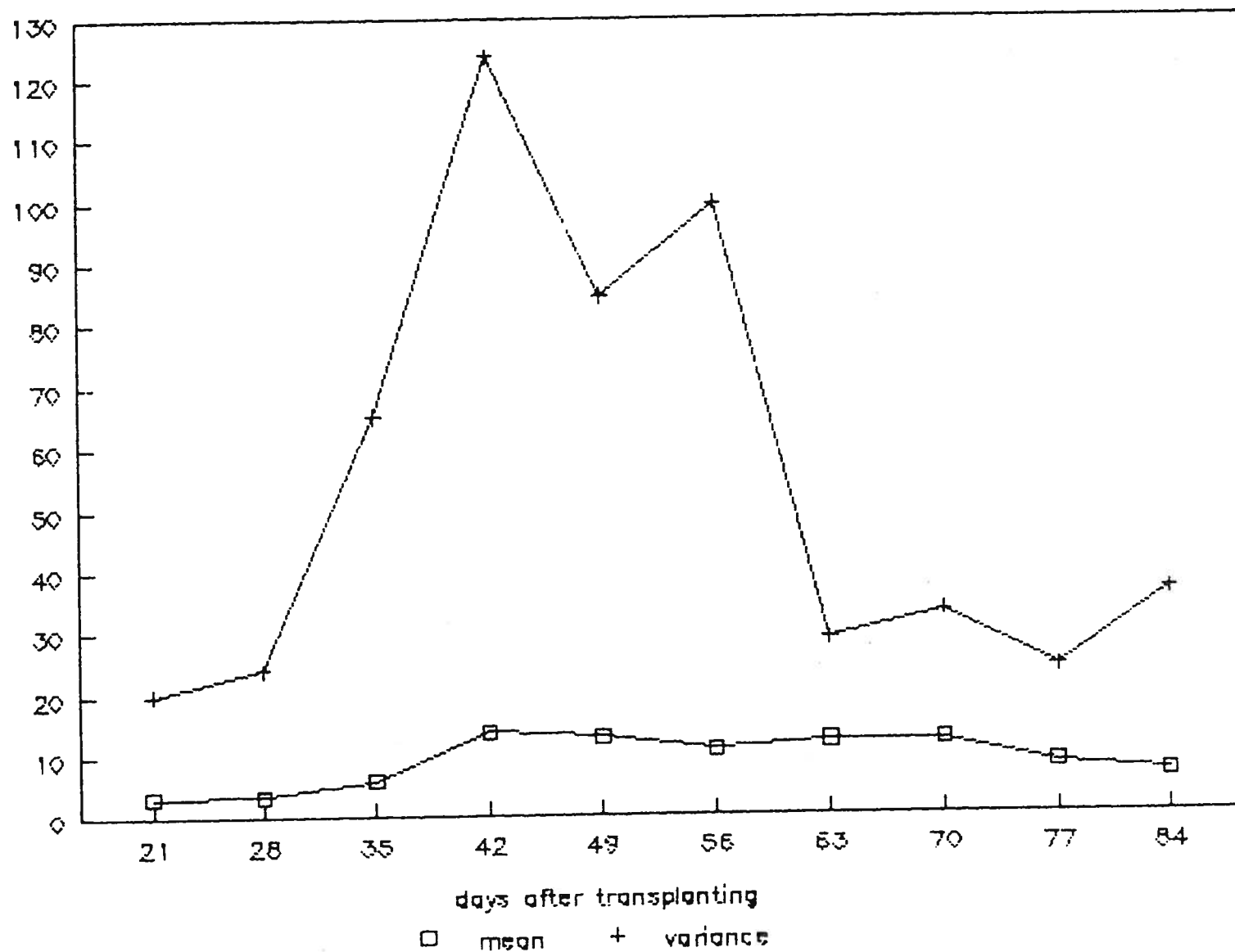


Fig. 22-b. Mean and variance of aphid on middle stratum on Golden Acre in late planting

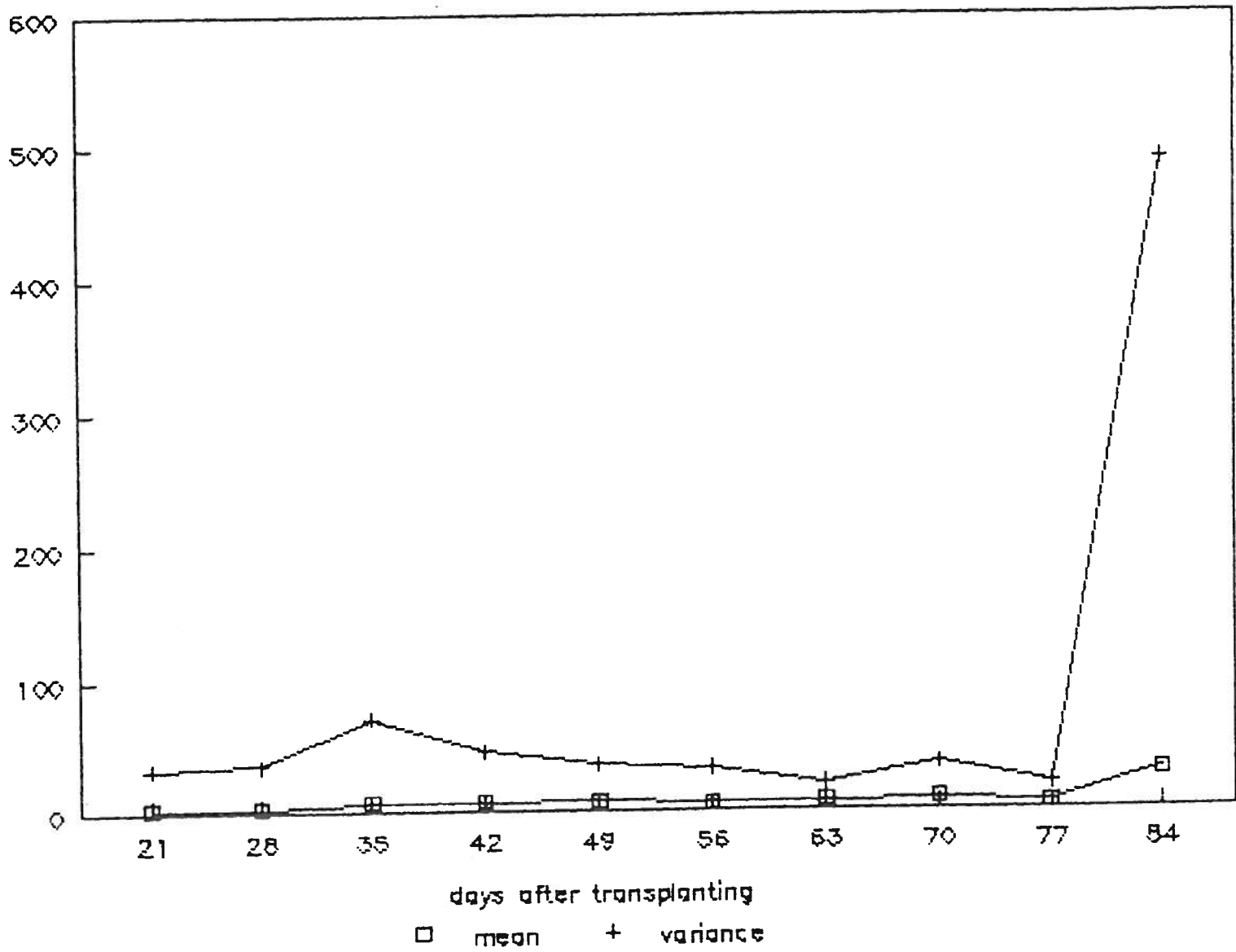


Fig 1 22-Mean and variance of aphid on bottom stratum on Golden Acre in late planting

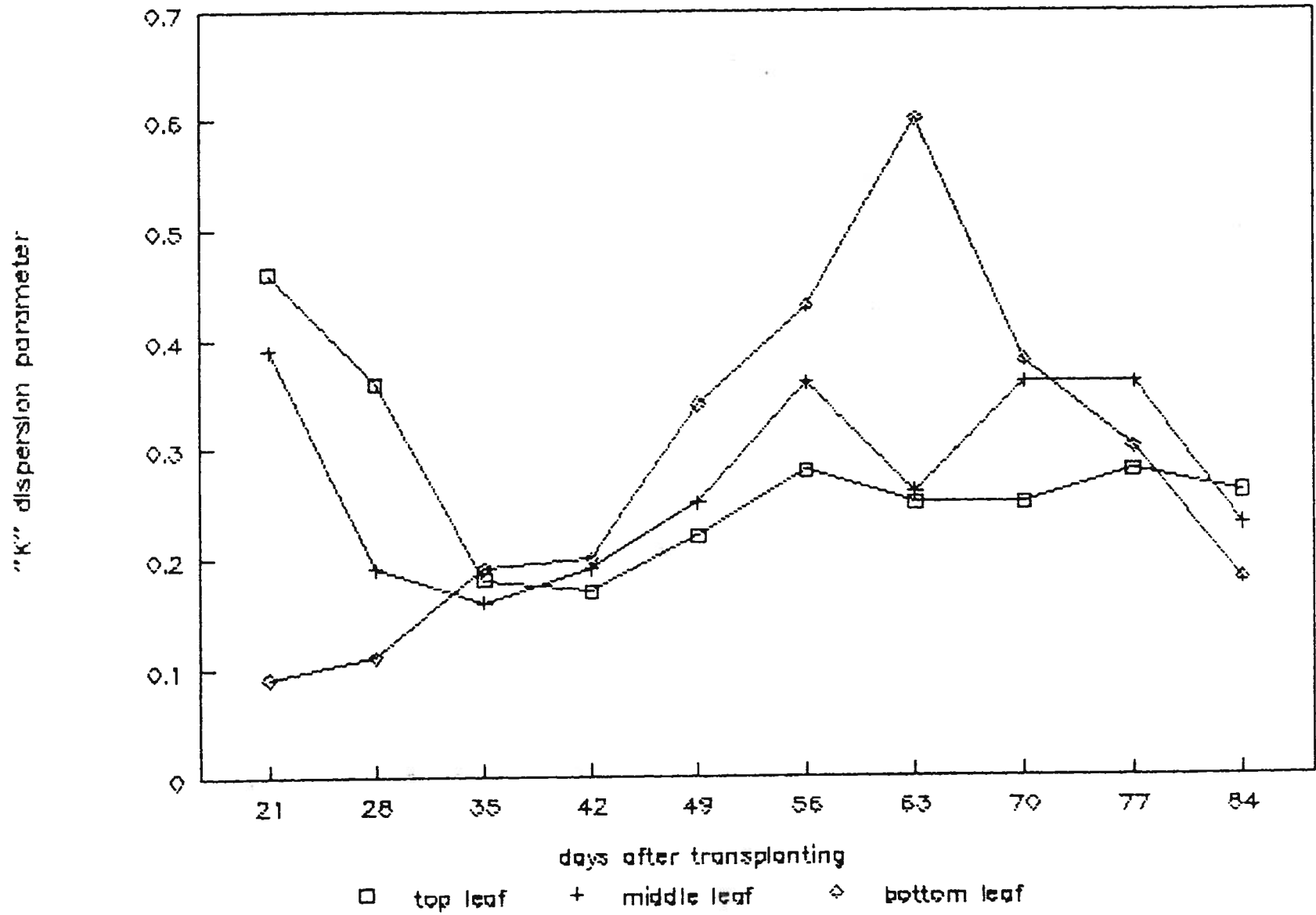


Fig 23 Dispersion parameter 'K' for aphid on different strata in Late Planting

Table 39: Standard Error Mean and Relative Variation of aphid in late planting

S.No.	Age of crop (days)	SEM			RV		
		Top leaf	Middle leaf	Bottom leaf	Top leaf	Middle leaf	Bottom leaf
1	7	-	-	-	-	-	-
2	14	-	-	-	-	-	-
3	21	3.17	3.98	6.55	22.88	26.87	35.34
4	28	1.65	4.80	7.11	21.75	28.16	31.06
5	35	12.22	13.05	14.05	22.99	27.29	22.87
6	42	55.58	24.73	9.06	16.51	16.31	18.39
7	49	30.78	16.86	7.12	13.63	14.32	15.15
8	56	19.46	19.92	6.49	15.32	18.55	17.47
9	63	11.91	5.74	4.11	9.14	8.84	12.39
10	70	9.35	6.66	7.06	7.73	9.34	12.70
11	77	10.12	4.80	4.14	11.05	11.72	14.87
12	84	12.00	7.29	98.02	13.00	17.55	14.88

- indicates no sampling

Lloyd's index of patchiness

The values of Lloyd's index of patchiness ranged from 9.97 to 137.78; 11.79 to 83.77 and 19.44 to 186.89 on top, middle and bottom strata. It is evident from the Table 35 that these values are greater than unity, indicating a negative binomial distribution.

Iwao's patchiness regression

Iwao's patchiness regression equation for different strata of the plant in late plantings are given below:

(1) For top strata

$$\bar{X}^* = 1.2825 + 1.2927 \bar{X} \quad (R^2 = 0.9075)$$

(2) For middle strata

$$\bar{X}^* = 2.6662 + 1.2236 \bar{X} \quad (R^2 = 0.7841)$$

(3) For bottom strata

$$\bar{X}^* = 1.9042 + 1.4311 \bar{X} \quad (R^2 = 0.9264)$$

The value of ω (index of basic contagion) and the value of β (density contagiousness coefficient) was greater than 1 in all the cases confirming that the aphids were following negative binomial distribution in all plant strata during late plantings.

4.6 EFFECT OF DIFFERENT TREATMENT SCHEDULES ON THE YIELD OF CABBAGE AND COST BENEFITS

The results of the yield pertaining to six treatment schedules during normal planting of 1991 are given in Table 40.

Table 40 : Effect of different treatment schedules on the cabbage.

Treatment	Mean yield kg ha ⁻¹
T ₁ Control	7687.50
T ₂ Maximum protection treatment	19950.00
T ₃ Need based application	7900.00
T ₄ Calender based application	11762.50
T ₅ Farmer's practice I	9100.00
T ₆ Farmer's practice II	12237.50
CD at 5% level	4298.65

The data showed that the plots which received two sprayings (T_3) gave a mean yield of 7900 kg ha^{-1} statistically at par with the yield in control which was $7687.5 \text{ kg ha}^{-1}$.

The maximum mean yield of 19950 kg ha^{-1} was obtained in the maximum protection treatment (T_2) which differed significantly from the rest of the treatment. In the maximum protection treatment carbofuran @ 8 kg ha^{-1} was applied at the time of nursery raising as well as transplanting and later four sprays of acephate @ 1 gm l^{-1} was applied at fortnightly intervals. None of the other treatments were found significantly at par with the maximum protection treatment.

Farmer's practice (T_6) recorded the next higher yield, (12237 kg ha^{-1}), while calender based application (T_4) recorded a yield of $11762.50 \text{ kg ha}^{-1}$. The need based application treatment T_3 gave the yield of 7900 kg ha^{-1} . The control plot gave a yield of $7687.5 \text{ kg ha}^{-1}$. The highest cost-benefit ratio was seen in T_6 (Farmer's practice) with a ratio of 1 : 26.14 and the lowest ratio was seen in T_3 (1 : 2.07), though the highest yields were recorded in T_2 the cost benefit ratio was 1 : 15.80 (Table 41).

...

Table 41 : Efficiency of insecticidal treatments against cabbage aphid cost-benefit ratio

Treatment	No. of sprays	Quantities of insecticides used	Total cost of insecticides	Cost of spraying operation	Total cost of insecticidal application	Yield (Kg/ha)	Extra yield (kg/ha)	Cost of increased yield	CBR
T ₁ Untreated control	-	-	-	-	-	7687.5			
T ₂ Maximum Protection treatment	4	8 kg carbofuran 3G 3.5 kg Acephate 75WP	2882.40	208.00	3090.40	19950.00	12262.50	49050.00	1:15.8
T ₃ Need based Application	2	1 Lt monocrotophos 36 SL	306.00	104.00	410.00	7900.00	212.50	850.00	1:2.07
T ₄ Calender based application	4	3.5 Kg Acephate 75 WP	2548.00	208.00	2756.00	11762.50	4075.00	16300.00	1:5.91
T ₅ Farmer's Practice (I)	3	1 Lt. Endosulfan + 500 ml Quinolophos 25 EC	310.00	156.00	466.00	9100.00	1412.50	5650.00	1:12.12
T ₆ Farmer's Practice (I)	3	3 Lt. Endosulfan	540.00	156.00	696.00	12237.50	4550.00	18200.00	1:26.14

Labour charges Rs. 42/- per hectare

Rental charges for sprayer Rs. 5/- per spray/day

Price of cabbage Heads Rs. 4/- per Kg.

CHAPTER V

DISCUSSION

Wealth of documented work on various aspects of cabbage pests is available yet, there remain many lacunae, particularly in the areas of seasonal incidence, intra and inter-plant distribution of key pests.

The studies on these aspects will help to fill the gaps in the existing knowledge so as to utilise the same to exploit the weak links if any in the chain of insects biology based on which a pragmatic integrated pest management programme could be evolved. Investigations have also been carried out to formulate effective and economical chemical control strategies.

PEAK INCIDENCE OF PESTS IN RELATION WITH ENVIRONMENTAL FACTORS**Aphid**

Cabbage aphid, B. brassicae infestation was high in early (August) planted crop when compared to the normal (October) and late (December) planted crop. The aphid attained a peak in the month of November in the early and normal planted crop (Table 1). Similar peak incidence was observed by few workers in November (Harinath Babu, 1985; Padmavathi, 1991) and in some instances the abundance was also recorded from November to April (Sachan and Gangawar, 1990). The incidence of aphids were relative low in the late (December) planted crop and there were two peaks both in the last week of January and second fortnight of

February (8th standard week) (Table 1). High incidence from mid February to April was also observed by Dhaliwal and Goma (1979).

The impact of weather parameters on the aphid population did not follow a set trend among the three plantings. The population of the aphid was found to increase with the increase in maximum temperature in the late planted crop (December) confirming the results of Dhaliwal and Goma (1979). In the early (August) planted crop only RH influenced the pest population build-up. The other weather parameters like rainfall, RH and minimum temperature did not affect the population build-up of the pest. Similar results were reported by Harvir Singh and Zile Singh (1989).

Diamond-back moth

Maximum incidence of DBM was found in the late planted crop with a peak in the first week of March (Table 5). Peak infestation of DBM was also observed during mid February and high incidence upto March (Sachan and Srivastav, 1972) and also at the end of January to first week of March (Bindra et al., 1977).

The influence of weather parameters on the population build-up of the pest revealed neither positive nor negative trend. Maximum and minimum temperature did not influence the population build-up of DBM in early and normal plantings, the results of which are in agreement with the reports of Lal (1939). In the early planting (August) the RH influenced the increase in population build-up confirming the results of Lal (1939).

Rainfall did not influence the population build-up confirming the results of Ong and Soon (1989). Harcourt (1963b) reported that the high mortality of DBM larvae is associated with rainfall.

Hellula

The incidence of H. undalis was seen only in the early planted crop with a peak in second fortnight of November whereas, in the normal and late planted crop there was no incidence (Table 6) Sachan and Srivastav (1972) also found this pest only in the early planted crop and it was attributed that the low temperatures in winter appeared to reduce the incidence of Hellula (Rawat et al., 1968).

Occurrence of Hellula in the last phase of crop growth in early planted crop may be due to the negative influence of maximum and minimum temperature and rainfall on the pest population build-up and positive effects of relative humidity. Rawat et al. (1968) reported that the population was not observed in the cooler months confirming the results obtained that no population was recorded in normal (October) and late (December) planted crop.

Crocidolomia

The incidence of leaf webber was also found in the early planted crop (Table 3) and no incidence was recorded in the normal and late planted crops. This results are in confirmity with that of Hsiae (1984) and Lee (1986).

Crocidolomia infestation in early planting only may be due to the negative influence of maximum and minimum temperature and rainfall on the pest population build-up and positive effects of relative humidity (Table 6). Whereas, Suman et al. (1980) contradictorily reported a positive correlation with temperature and negative correlation with humidity.

DISTRIBUTION OF CABBAGE PESTS

Aphid

Spatial distribution of pests infesting the cabbage in field were evaluated initially with the simplest method of first finding the variance and mean of their populations (Table 11 and 12). In all the cases the variance values were more than mean which indicated that aggregative distribution will fit the data (Southwood, 1978). The relation between variance and mean increased linearly with the rise of mean and exceeded unity, suggesting that the aphids distribution could be aggregative (Kuno, 1963).

The aggregative nature of the distribution is also described by the exponent 'K' of negative binomial distribution. Based on the values of 'K', we can measure the amount of aggregation or clumping and is often referred to as dispersion parameter (Anscombe, 1949). The value of 'K' normally lies below '8', in cases where the pest is following negative binomial distribution. In cases where the value of 'K' exceeds '8' the distribution pattern of the pest tends to random or Poisson (Southwood, 1978).

In present study, the value of 'K' were estimated by several methods. The value of 'K' was computed by approximation as suggested by Katti and Gurland (1962), secondly from proportion of zeroes and the thirdly, by trial and error (Iterative) method. For all practical purposes the value of 'K' derived from trial and error method is taken for further confirming the nature of distribution of the pest. In the present study the computed values of 'K' by Iterative method was much lower than 8 in both the varieties in Golden Acre (0.09-0.37) and in Pride of India (0.06 - 0.37) in all the three (early, normal and late) plantings. It is generally inferred that lower the values of 'K' higher the degree of clumping. It can also be inferred that among the three plantings during early planting on both the varieties 'K' values were lower suggesting a higher degree of aggregation. However, in any case, the values of 'K' never exceed '8' in all the three plantings and on both varieties suggesting that the population of cabbage aphid is following a negative binomial distribution. Such a distribution of insect populations has been reported by several workers (Bliss and Owen, 1958; Harcourt, 1965; Safranyik and Raske, 1970; Allen et al., 1972; Kogan et al., 1974; Latheef and Pass, 1974; Clement and Christensen, 1979; Suman and Wahi, 1981; Wilson et al., 1983; Paras Nath and Mishra, 1986; Mahal et al., 1988; Singh, 1989 and Singh, 1991) for different insect populations.

Southwood (1978) opined that binomial distribution is mainly due to the fact that the species may aggregate in the same

habitat because it does not disperse or that it reproduces more only on certain parts of the habitat which are suitable for it. It is difficult to explain this phenomenon in the present case with certainty but it may be said that specific sites selected by the winged aphids during first finding and also due to the parthenogenetic reproduction the chances of its dispersal are minimised and probably led to such a type of distribution.

A common clumping parameter (K_c) was worked out for cabbage aphids by moments and regression method as suggested by Elliot (1979). The values obtained are 1.53; 3.02 and 2.40 in early, normal and late plantings on variety Golden Acre while on Pride of India the values were 1.20, 3.14 and 3.11 respectively. Two statistics X' and Y' when plotted against each other showed that most of the points were in close proximity of the main trend (Fig.12). This justified the estimation and accuracy of common 'K' (K_c). These findings are in confirmity with that of Bliss (1958), Bliss and Owen (1958). The homogeneity of the samples was tested graphically by plotting $1/k$ against mean (X) (Fig.13a to 13f). It did not show any trend or clustering justifying the fitting of the common 'K' value (Bliss and Owen, 1958).

INDICES OF DISPERSION FOR CABBAGE APHID

The nature of distribution of aphids was further confirmed by working out the different indices of dispersion. The variance to mean ratio index of dispersion (I) in all the three plantings of both the varieties were computed, where, the value

of I departed from unity in all the weeks of observation (Table 20) confirming the aggregated nature of distribution of the cabbage aphid. Further, the values obtained from the David and Moore's and Morista's index were found to be greater than the values of maximum regularity and random values (Table 23) and these values tended towards maximum contagion which again confirmed the contagious nature of distribution. These results are in confirmity with the findings of Paras Nath and Misra (1986).

The Morista's index of dispersion which is independent of parental distribution, also showed values greater than unity (Table 26). This indicates that the aphid population tends to be aggregated or contagious. These results are in confirmity with that of Suman and Wahi (1980).

The value of Taylor's Power law where the value of index of aggregation (b) and sampling factor (a) were greater than one clearly indicated the over dispersed nature of distribution of the aphid. The homogeneity in the values of index of aggregation 'b' indicated a consistency of the index in three plantings in both the varieties (Taylor, 1961). Higher values of coefficient of determination (R^2) suggested strong relationship between the values of mean and variance and good fit of Taylor's power law to cabbage aphid counts.

All these statistical tests amply proved that the aphids on cabbage crop followed a negative binomial distribution.

Intra-plant distribution of aphid

Within plant distribution of an insect, indicates preference for various plant parts and the mobility of the pest on a host. From an applied aspect this information indicates the synchrony of a pest with its host plant portion and aids in the development of economic, less time consuming and quick sampling procedures.

The data on intra-plant distribution of the cabbage aphid was subjected to frequency distribution and the mean and the variance was calculated separately for top, middle and bottom strata in every week and the variance was found to be greater than mean indicating an aggregated or contagious nature of distribution. The present findings thus, clearly showed that within plant distribution of aphids on cabbage crop too was not uniform and on most of the sampling dates the top stratum of the plant contained maximum number of aphids. The higher densities of aphid on top stratum could be due to the availability of succulent leaves in this region of the plant that helped in continuous drain of cell sap of plants.

The value of 'K' by Iterative method (Trial and Error method) computed for all the weeks in the early, normal and late planted crop of the top, middle and bottom strata (Tables 33, 36 and 38) were much below the value of 8 indicating highly contagious nature of the aphid population. Similar nature of distribution was observed by Bliss and Owen, 1958; Harcourt, 1965; Kogan

et al., 1974; Paras Nath and Mishra, 1986; and Mahal et al., 1988).

The relative variance (RV) was used as a measure of reliability of samples from different strata of the plant by Chakravarthy and Anand Rao (1985). In the present investigations the RV values for the top, middle and bottom strata of the plant during early were (11.83 to 31.26; 11.46 to 59.07 and 0.83 to 46.07), in normal (9.83 to 29.06; 7.92 to 25.41 and 9.06 to 29.85) and in late (7.73 to 22.99; 8.84 to 28.16 and 12.39 to 35.34) plantings, indicated that the top stratum of the plant provided a maximum probability of finding the highest aphid infestation compared to middle and bottom stratum and thus sampling aphids from this stratum could afford a reliable estimate of their density.

In order to confirm the nature of distribution of aphid in different strata, Lloyd's index of patchiness was calculated by dividing the mean crowding with their respective mean density values. The value of Lloyd's patchiness index was greater than unity confirming the contagious or aggregated nature of distribution of the aphid in all the three strata. The results are in confirmity with the reports of Tandon and Shukla (1988).

Iwao (1968) showed that in a regression of mean crowding on mean density, the regression constants are characteristic to respective distribution. The slope 'b' is called as the density contagiousness coefficient, is an index showing how such basic

components distribute themselves in the habitat. The value of from Iwao's Patchiness regression departed from unity indicating that the aphid population is following an aggregated distribution. These results are in confirmity with the results of Latheef and Pass (1973).

DBM

Like the cabbage aphid, for DBM also the variance was found to be more than mean in all the weeks of observation for both the cabbage varieties for all the plantings (Tables 13 & 14) indicating an aggregated or contagiousness nature of distribution. The aggregative nature of distribution is described by the exponent 'K' of negative binomial distribution where the value of 'K' in all the cases of observation was less than 8 (Table 21) confirming the aggregated nature of distribution. Such a nature of distribution was reported by many workers (Harcourt, 1960; Iwao, 1970a; Chua and Lim, 1977; Chua and Lim, 1979; Chen and Su, 1980 and Srinivasan and Rao, 1987) for various insects.

Common clumping parameter (K_c) worked out for DBM by moments and regression method for early, normal and late plantings on variety Golden acre and Pride of India represented by a graph plotted between X' and Y' showed that most of the points were in close proximity of main trend (Fig. 14). This justified the estimation and accuracy of common 'K' (K_c). The results were comparable with that of Bliss (1958) and Bliss and Owen (1958).

INDICES OF DISPERSION

In order to further confirm the nature of distribution of DBM different indices of dispersion were worked out. The variance to mean ratio 'I' indicated (Table 21) that the values departed from unity indicating a contagious nature of distribution of DBM.

The values obtained by David and Moore's index indicated that the values were greater than the values of maximum regularity and random values (Table 24) and these values tended towards maximum contagion thus confirming the contagious nature of distribution similar to that obtained by Goh and Lange (1980).

Similarly the values of Morista's index were greater than unity (Table 27) indicating an aggregative nature of distribution of the pest. Similar results were also reported by Srinivasan and Rao (1987).

The Taylor's power law was computed for all the weeks of observation. The value of 'b' in all the three plantings and on both varieties were greater than unity (Table 29) indicating an aggregated nature of distribution of DBM which confirmed the findings of Chen and Su (1986).

Cabbage head borer and cabbage leaf webber

The data collected for both Hellula and Crocidolomia which appeared for brief period on both varieties when arranged in a frequency distribution and the mean and variance for each

week of observation clearly indicated that the values of variance were greater than mean in all cases confirming an aggregated nature of distribution. The aggregated nature of distribution was further confirmed by calculating the 'K' values. The values of 'K' in all cases of observation were below 8 (Table 22) of further confirming the aggregated, nature of distribution of these pests.

Other indices of dispersion i.e., variance to mean ratio ; David and Moore's, Morista's index were worked out. Taylor's power law was finally worked out and the results confirmed that these pests followed an aggregated type of distribution. Similar aggregated type of distribution was reported by Kogan et al. (1974) , Chua and Lim (1979), Chen and Su (1980) and Srinivasan and Rao (1987).

Effect of different treatment schedules on the yield of cabbage

Different spray schedules were taken up at different stages of crop growth in order to maintain a differential gradient population level of the aphid. This is done in order to get variability in the population level. The yields obtained in each of the treatments are shown in Table 41. The highest mean yield of 19950.00 kg ha⁻¹ was obtained in the maximum protection treatment (T₂) and the yield differed significantly from the yield obtained in Farmers practice (T₆) which recorded an yield of 12237.50 kg ha⁻¹. All the other treatments did not differ significantly from the control.

It was seen that when the crop is being protected from the nursery and also after transplanting in main field the yield obtained was maximum (T_2). In comparison with the two Farmers practices (T_5 and T_6), it is seen that the Farmer's practice II (T_6) recorded a higher yield (12237.00 kg/ha). This can be attributed to the reason that the chemical sprays were higher and control measures were at timely intervals. The need based application treatment (T_3) recorded a low mean yield as only two sprays of chemical were taken up and the yield was almost on par with that of control (no treatment) plot T_1 which recorded an yield of 7687.50 kg ha⁻¹.

Effect of different insecticides on yield and cost-benefit ratio

The cost-benefit ratio was highest in the case of Farmer's Practice II (T_6), where for every rupee invested the returns obtained was Rs.26.14 because of taking up control at the right time of infestations using less number of sprays. Even though the treatment T_2 which recorded the highest yield among all the treatments had only the cost-benefit ratio of 1:15.80. Due to the fact that there was a significant difference in yields of T_2 and T_6 the cost of protection measures i.e., the chemicals used were high. Therefore, it is inferred that before taking up control measures one should bear in mind the gains which he is going to reap after harvest. Such studies were carried out earlier by Padmavathi (1991) using different chemicals and treatments.

CHAPTER VI

SUMMARY

The present investigation on "Ecology and control of key pests of cabbage", was undertaken during 1991-92 at the Students' Farm, College of Agriculture, Rajendranagar, Hyderabad. The seasonal incidence and effect of abiotic factors on the population build-up of aphid, DBM, cabbage head borer and leaf webber were studied, on two varieties viz., Golden Acre and Pride of India. Data pertaining to the pest population was collected from the field to study the distribution of the pest. The intra-plant distribution of the aphid was studied on Golden Acre. Effect of different treatments and cost-benefit ratio of these treatments were worked out in the present study.

APHID

The early (August) planted crop harboured high incidence of aphid when compared to normal (October) and late (December) planted crop. The variety Pride of India appeared to be more susceptible to aphid incidence than the variety Golden Acre. Among various weather parameters, RH showed a positive influence on aphid population in the early planted crop and maximum and minimum temperature showed a positive effect in the late planted crop. All the weather parameters showed a negative influence on the pest population in the normal planted crop.

The pest incidence was recorded only for three plantings, but as the crop is grown throughout the year, except

in summer in and around Hyderabad, the pest incidence can be studied in several plantings and the seasonal incidence of pests can be ascertained.

The cabbage aphid was found to be distributed in a contagious or aggregated pattern as was indicated by greater variance values over their respective means for all the weeks. The dispersion parameter 'K' was calculated and its value was less than eight indicating contagious nature of the pest. An approximation was made by applying variance/mean ratio which was in agreement with negative binomial distribution. Similarly, the indices of dispersion tested also confirmed the aggregated distribution of the cabbage aphid.

Life tables can be conducted for the aphid so that it would give substantial information on the key mortality factors of these pest.

The intra-plant distribution showed that the pest followed an aggregated distribution as the variance was greater than mean. It was confirmed by estimating the dispersion parameter 'K' and employing other indices of dispersion. It was seen that the top strata harboured more number of aphids compared to the middle and bottom strata of the plant.

Out of the six treatments tested, maximum protection treatment (T_2) gave highest yield and was significantly higher than the other treatments. The cost benefit ratio was found to be

highest for Farmer's Practice II (T_6) followed by T_2 .

Yield infestation studies can be carried out and the EILs fixed by creating graded levels of infestation. Sequential sampling plan can be developed and tested in farmer's field to confirm its accuracy.

DBM

The late (December) planted crop showed higher incidence of DBM when compared to the early (August) and normal (October) planted crop. Among the weather parameters, only RH exerted a positive influence in the early plantings. In the late plantings, maximum and minimum temperature exerted a positive influence, whereas, in the normal plantings none of the weather parameters influenced the population build-up.

The nature of dispersion was confirmed as aggregated or contagious as the variance was greater than mean in most of the weeks of observation except in second, fifth and sixth week of observations in early planting in var. Golden Acre and second and fifth week in Pride of India in normal planting and first and ninth in Golden Acre and first in Pride of India in late planting where a positive binomial distribution was noticed. The distribution was further confirmed by computing 'K' by Trial and Error Method where the values were less than '8'. The other indices of dispersion also confirmed the aggregated nature of distribution.

The yield-infestation relationships were carried out but the data did not fit into the equations as the DBM population was zero in most of the weeks of observation.

Hellula and Crocidolomia

These pests were recorded only in the early (August) planting just one month before the harvest of the crop on both the varieties. Among the various weather parameters, only RH exerted a positive influence on the pest population build-up.

The distribution of the pest followed an aggregated distribution as the variance was greater than mean and this was further confirmed by calculating 'K' where the values were less than '8' and by other indices of dispersion.

In future, to fill up the lacunae in research the following areas need be worked upon, vertical and horizontal distribution of different stages of the lepidopterous pests, intra-plant distribution of these pests, working out yield infestation relations and thereby fixing EIL's and developing a sequential sampling plan.

...

Appendix I: Meteorological data during the experimental period

Standard Week No.	Dates	Temperature (°C)		Relative humidity (%)	Total Rain- fall (mm)
		Maxi- mum	Mini- mum		
33	13 - 19 Aug.	29.9	22.3	84	20.8
34	20 - 26	30.0	19.1	79	16.2
35	27 - 02 Sept.	30.6	22.1	71	0.0
36	03 - 09	31.6	22.8	70	1.8
37	10 - 16	32.0	22.8	67	0.0
38	17 - 23	31.3	22.5	76	155.4
39	24 - 30	31.6	21.3	74	0.0
40	01 - 07 Oct.	32.2	21.5	74	2.8
41	08 - 14	32.1	29.7	87	46.4
42	15 - 21	31.3	20.1	85	0.0
43	22 - 28	30.4	15.8	70	2.2
44	29 - 04 Nov.	27.2	21.0	85	6.0
45	05 - 11	29.4	14.5	77	0.0
46	12 - 19	27.1	15.4	79	7.2
47	20 - 26	27.9	16.7	79	0.0
48	27 - 03 Dec.	29.5	12.8	75	0.0
49	04 - 10	28.1	9.8	72	0.0
50	11 - 17	26.9	9.5	71	0.0
51	18 - 24	27.6	11.9	75	0.0
52	25 - 31	28.9	14.1	75	0.0
1	01 - 07 Jan.	28.1	9.6	61	0.0
2	08 - 14	28.3	8.8	61	0.0
3	15 - 21	28.9	12.1	65	0.0
4	22 - 28	30.4	13.2	64	0.0
5	29 - 04 Feb.	30.5	12.5	67	0.0
6	05 - 11	32.1	15.5	64	0.0
7	12 - 18	32.5	13.1	61	0.0
8	19 - 25	32.6	16.1	61	0.0
9	26 - 03 Mar.	33.6	14.2	55	0.0
10	04 - 10	36.6	15.9	45	0.0
11	11 - 17	36.9	18.0	48.8	0.0
12	08 - 24	38.4	19.4	53.1	0.0

LITERATURE CITED

- Abraham E V and Padmanabhan M D 1967 Bionomics and control of the diamond-back moth Plutella maculipennis Curt. Indian Journal of Agricultural Sciences 38(3) : 513-519.
- Allen J, Gonzalex D and Gokhale D V 1972 Sequential sampling for the boll worms Heliothis zea. Environmental Entomology 1(6) : 771-780.
- Anderson R M 1974 Population dynamics of cestode Caryophyllaeuts laticeps in the bream (Abramis brama L.). Journal of Animal Ecology 43 : 305-321.
- Anscombe F J 1948 On estimating the population of aphids in a potato field. Annals of Applied Biology 35 : 567.
- Anscombe F J 1949 The statistical analysis of insect counts based on the negative binomial distribution. Biometrics 5 : 165-173.
- Anscombe F J 1950 Sampling theory of negative binomial and logarithmic series of distribution. Bio metrika 37 : 358-382.
- Bindra O S, Singh D and Ramzan M 1977 Seasonal abundance of insect pests of cauliflower at Ludhiana (Punjab). Journal of Research Punjab Agricultural University 14 : 66-69.
- Blackman R L and Eastop V F Aphids on the world crops: An identification and information guide. John Wiley and Sons pp.413.
- Bliss C I 1958 The analysis of insect counts as negative binomial distribution. Proceedings of X International Congress of Entomology 2 : 1015-32.
- Bliss C I and Fisher R A 1953 Fitting the binomial distribution to biological data and a note on efficient fitting of the negative binomial. Biometrics 9 : 176-200.
- Bliss C I and Owen A R G 1958 Negative binomial distribution with a common 'K'. Biometrika 45 : 37-58.

- Chakravarthy A K and Ananda Rao P K 1985 Dispersion patterns, sample unit sizes and techniques for sampling cotton jassid [Amrasca biguttula biguttula (Ishida)] and white fly (Bemesia tabaci Genn). Insect Science and its Application 6(6) : 661-665.
- Chen C N and Su W Y 1986 Spatial pattern and transformation of field counts of Plutella xylostella larvae on cauliflower. Plant Protection Bulletin, (Taiwan) 28 (3) : 323-333.
- Chin T 1974 Studies on seasonal appearance of diamond-back moth in relation to environmental factors. Taiwan Agriculture Quarterly 10(4) : 81-84.
- Clement S L and Christensen J B 1979 Studies on the spatial patterns of chironomid larvae in California Rice paddies. Environmental Entomology 8(4) : 676-678.
- Chua T H and Lim B M 1977 Effect of interplant distance on the distribution pattern of diamond back moth Plutella xylostella (L.) among host plants. Malaysian Applied Biology 6 : 19-23.
- Chua T H and Lim B M 1979 Distribution pattern of diamond back moth, Plutella xylostella (L.) (Lepidoptera : Plutellidae) on choy-sum plants. Zertschrift fur Angewandte Entomologie. 88 : 170-175.
- Cole L C 1946 A theory for analyzing contagiously distributed populations. Ecology 27 : 329-341.
- David F N and Moore P G 1954 Notes on contagious distributions in plant populations. Annals of Botany 18 : 47-53.
- Dean G J W 1973 Distribution of aphids in spring cereals. Journal of Applied Ecology 10 : 447-462.
- De Bauche H R 1962 The structural analysis of animal communities in the soil. In progress in Zoology (ed PW Murphy) London. Pp 10-25.
- Dhaliwal H S and Goma B D 1979 Seasonal abundance of various insect pests on cauliflower seed crop in lower hills of Solan, India. Indian Journal of Ecology 6 : 101-109.

- Elliott J M 1977 Some methods for the statistical analysis of samples of benthic invertebrates. Fresh Water Biological Association Scientific Publication No. 25.
- Elliott J M 1979 Some methods for statistical analysis of samples of benthic invertebrates. Science Publication of Fresh Water Biology Association Publication Number 25 157 pp.
- Emmett B J 1980 Key for the identification of lepidopterous larvae infesting brassica crops. Plant Pathology 29 : 122-123.
- Evans D E 1972 The spatial distribution and sampling of Aeneolamia varia saccharina and A.postica jugata (Homoptera : Cercopidae) Entomologia Experimentalis et Applicata 15(3) : 305-318.
- Fagoonee I 1980 The life-cycle bionomics and control of the cabbage web worm, Crocidolomia binotalis Zell (Lepidoptera : Pyralidae) Revue Agricole et Sucriere de l' Ile Maurice 59(2) : 57-62.
- Gandhale D N, Salunkhe G N and Naik L M 1982 Effectiveness of insecticides for the control of aphids (Brevicoryne brassicae L.) on cabbage. Indian Journal of Plant Protection 10 (1/2) : 85-86.
- Gera S S and Bhatnagar K N 1992 Seasonal incidence of pest complex of cabbage and their control in semi-arid region. Pestology 26(3) : 38-45.
- Harcourt D G 1960 Distribution of immature stages of diamond back moth Plutella maculipennis (Curt) (Lepidoptera : Plutellidae) on cabbage. Canadian Entomologist 82:517-521.
- Harcourt D G 1961 Spatial pattern of the imported cabbage worm, Pieris rapae (L.) (Lepidoptera : Pieridae) on cultivated crucifers. Canadian Entomologist 83:945-52.
- Harcourt D G 1963a Population dynamics of Leptinotarsa decemlineata (Say) in Eastern Ontario I. Spatial pattern and transformation of field counts. Canadian Entomologist 95 : 813-20.

- Harcourt D G 1963b Major mortality factor in the population dynamics of DBM Plutella maculipennis (Lepidoptera: Plutellidae). Canadian Entomologist 93 : 820-831.
- Harcourt D G 1965 Spatial pattern of the cabbage looper Trichoplusia ni on crucifers. Annals of Entomological Society of America 58(1) : 89-94.
- Harcourt D G 1967 Spatial arrangement of the eggs of Hylemya brassicae (Bouche) and a sequential sampling plan for use in control of the species. Canadian Journal of Plant Sciences 47 : 461-67.
- Harinatha Babu K 1985 Population dynamics and control of certain important pests of cabbage. M.Sc. thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.
- Harvir Singh and Zile Singh 1989 Population dynamics of green peach aphid (Myzus persicae Sulz.) on rape seed Cv. BSH 1. Crop Research 2(2): 194-199.
- Hassel M P and May R M 1974 Aggregation of predators and insect parasites and its effect on stability. Journal of Animal Ecology 43 : 567-594.
- Hayman B I and Lowe A D 1961 The transformation of counts of the cabbage aphid (B. brassicae). New Zealand Journal of Science 4: 271-278.
- Herakly F A and El-Ezz A A 1970 Seasonal abundance and natural enemies of the cabbage aphid, Brevicoryne brassicae L. in UAR Agricultural Research Review 48(1) : 119-122.
- Ho T H 1965 The life-history and control of the diamond back moth in Malaya Bulletin Division, Agriculture of Malaysia (Bull. Div. Agric. Malays.) 118 : 1-26.
- Hsiae W F 1984 The bionomics of cabbage leaf webber, Crociodolomia binotalis Zell. (Lepidoptera: Pyralidae). Plant Protection Bulletin (Taiwan) 26(3) : 257-261.

- Ibarra E L, Wallwork J A and Rodriguez J G 1965 Ecological studies of mites found in sheep and cattle pastures 1 Distribution patterns of Oribatid mites. Annual Entomological Society of America 58 : 153-159.
- *Ishi T 1938 Important insect pests of vegetables 1-3 (In Japanese). Agriculture and Horticulture 13 : 1237-1244.
- Iwao S 1968 A new regression method for analysing the aggregation pattern of animal populations. Researches on Population Ecology 10 : 1-20.
- Iwao S 1970 Analysis of spatial patterns in animal populations - progress of research in Japan. Japanese Review of Plant Protection Research 3: 41-54
- Katti S K and Gurland J 1962 Efficiency of certain methods of estimation for the negative binomial and the Neyman type A distributions. Biometrika 49 : 215-228.
- Khaira V A, Lawande K E and Ajri D S 1987 Population dynamics of insect pests of cabbage. Current Research Reports, Mahatma Phule Agriculture University 3(1) : 27-31.
- *Kirti Singh 1991 'Total system' approach wanted. pp.192-195. In The Hindu Survey of Indian Agriculture (Ed.) Ravi N. National Press.
- Kogan M, Ruesink W G and Mc Dowell 1974 Spatial and temporal distribution patterns of bean leaf beetle Ceratoma trifurcata (Forster) on soybeans in Illinois. Environmental Entomology 3(4) : 607-617.
- Kotwal D R and Bhalla O P 1983 Prediction of the cabbage aphid population peak on cauliflower seed crop. Indian Journal of Plant Protection 11(1/2) : 76-77.
- Krishnaiah K and Mohan N J 1983 Control of cabbage pests by new insecticides. Indian Journal of Entomology 45 : 222-228.
- Krishnaiah K, Mohan N J and Bagle B G 1979 Control of major pests of cabbage by new insecticides. Indian Journal of Plant Protection 6(2) : 44-47.

- Kuno E 1963 A comparative analysis on the distribution of nymphal populations of some leaf and plant hoppers on rice plant. *Researches on Population Ecology* 5 : 31-43.
- Lal K B 1939 Natural and biological control of Plutella maculipennis Curt. in England. *Indian Journal of Entomology* 1: 117.
- Latheeff M A and Pass B C 1974 Spatial distribution of Hypera postica in Kentucky alfalfa fields. *Environmental Entomology* 3(5) : 866-871.
- Lee H S 1986 Seasonal occurrence of the important insect pests on cabbage in Southern Taiwan. *Journal of Agricultural Research of China* 35(4) : 530-542.
- Legay J M 1963 A purpose 'de lare' partition de la cecidomyie du Metre, Milaiola Faq un exemple de distribution binomial negative. *Annual Epiphyte* 14 : 49-56.
- Lloyd M 1967 Mean crowding. *Journal of Animal Ecology* 36 : 1-30.
- Lyons L A 1964 The spatial distribution of two pine sawflies and methods of sampling for the study of population dynamics. *Canadian Entomologist* 96 : 1373-1407.
- Mac Gillivray H J 1961 Vegetable production. Mc Graw Hill Book Company, New York pp.387.
- Mahal M S Rajwant Singh and Balraj Singh 1988 Dispersion of Lipaphis erysimi (Kalt) and development of a sequential sampling plan for its supervised control on raya. Brassica juncea Coss. *Journal of Insect Science* 1(1) : 27-38.
- Mohan N J, Krishnaiah K and Kumar N K K 1981 Chemical control of mustard aphid, Lipaphis erysimi Kalt. and leaf webber. Crociodomia binotalis Zell on cabbage. *Pesticides* 15(2) : 29-32.
- Mohite P B and Moholkar P R 1988 Efficacy of different pesticides against aphids on cabbage. *Pesticides* 22(7) : 35-36.

- Morista M 1962 a measure of dispersion of individuals. *Researches on Population Ecology* 4 : 1-7.
- Morris R F 1955 The development of sampling technique for forest insect defoliators with particular reference to spruce bud worm. *Canadian Journal of Zoology* 33 : 225-94.
- Morris R F 1960 Sampling insect populations. *Annual Review of Entomology* 5 : 243-64.
- Ong K M and Soon S C 1989 Seasonal abundance and distribution patterns among host plants of diamond back moth (Plutella xylostella (L.)). *Singapore Journal of Primary Industries* 17(1) : 29-40.
- Padmavathi Ch 1991 Seasonal incidence and chemical control of certain important pests of cabbage. M.Sc. thesis submitted to Andhra Pradesh Agriculture Univesity, Hyderabad pp.131.
- Patil G P and Stiteler W M 1974 Concepts of aggregation and their quantification : A critical review with some new results and applications. *Researches on Population Ecology* 15 : 238-254.
- Parasnath and Mishra D S 1986 Distribution behaviour of Lipaphis erysimi on Raya var. Varuna. *Proceedings of 2nd National Symposium. Recent Trends in Aphidotogical Studies, Modinagar* (Ed.) S.P. Kurl. pp 47-54.
- Pearson E S and Hartley H O 1966 *Biometrical tables for statisticians* (3rd edition) Cambridge.
- Peter C, Balasubramanian R and Prasad V G 1987 Studies on the biology of the cabbage borer, Hellula undalis Fabricius (Lepidoptera: Pyralidae) in Karnataka Mysore *Journal of Agricultural Sciences* 21 : 309-312.
- Pieters E P and Sterling W L 1974 Aggregation indices of cotton arthropods in Texas. *Environmental Entomology* 3(4) : 598-600.
- Prasad S K 1952 Studies on distribution and sampling of mustard aphid Lipaphis erysimi Kalt. on mustard crop. M.Sc. thesis, Indian Agricultural Research Institute, New Delhi.

- Rao K N, George C J and Sastri K SR 1971 Climate classification of India Science Reporter Number of Indian Meteorological Department, Pune, India.
- Rawat R R, Rathore Y S and Saxena D K 1968 Biomimics of Hellula endalis F. the cabbage borer (Pyrallidae : Lepidoptera) at Jabalpur. Indian Journal of Entomology 30(3) : 235-237.
- Ruesink W G 1980 Introduction to sampling theory. In Sampling methods in soybean entomology Springer Publishing Co., New York, pp 61-78.
- Sachan J N and Gangawar S K 1990 Seasonal incidence of insect pests of cabbage cauliflower and knol-khol. Indian Journal of Entomology 52(1) : 111-124.
- Sachan J N and Srivastava B P 1972 Studies on the seasonal incidence of insect pests of cabbage. Indian Journal of Entomology 34(2) : 123-129.
- Safranyik L and Raski A G 1970 Sequential sampling plan for larvae of Monochamus in lodgepole logs. Journal of Economic Entomology 63(6) : 1903-1906.
- Sarode S V and Kumar K K 1983 Efficacy of some granular insecticides against major pests of cabbage. Pesticides 17 : 26-27.
- Singh S H 1991 Sampling and Distribution of safflower aphid, Uroleucon compositae (Theobald). M.Sc. thesis submitted to Andhra Pradesh Agriculture University, Hyderabad pp.176.
- Singh T V K 1989 Certain aspects of insect pest management in groundnut Arachis hypogaea Linn. Ph.D. thesis submitted to P.G.School at I.A.R.I., New Delhi
- Snedecor G W and Cochran W G 1967 Statistical methods. Ames Iowa pp 593.
- Southwood T R E 1978 Ecological methods with particular reference to the study of insect populations. The English Language Book Society, Chapman and Hall, London pp.524.

- Srinivasan K and Rao G S P 1987 Distribution patterns of diamond back moth and cabbage leaf webber larvae on cabbage. *International Journal of Tropical Agriculture* 5(3-5): 203-208.
- Suman C L and Wahi S D 1981 Sequential sampling plan for the onion thrips Thrips tabaci (Lind). *Entomology* 6(3): 265-269.
- Suman C L, Wahi S D and Prasad V G 1980 Distribution behaviour of cabbage leaf-webber. *Journal of Agricultural Sciences* 50(10): 785-787.
- Talekar N S and Lee S T 1985 Seasonality of insect pests of Chinese cabbage and common cabbage in Taiwan. *Plant Protection Bulletin, Taiwan* 27(1) : 47-52.
- Tandon P L and Bhalla O P 1977 Control of cabbage aphid with granular systemic insecticides through soil. *Indian Journal of Entomology* 38(2): 181-186.
- Tandon P L and Shukla R P 1988 Intra-tree spatial distribution of eggs and egg colonies of Aleurocanthus woglumi (Homoptera) on lime. *Entomon* 13(1): 1-8.
- Taylor L R 1961 Aggregation, variance and the mean. *Nature* 189 : 732-735.
- Taylor L R 1984 Assessing and interpreting the spatial distributions of insect populations. *Annual Review of Entomology* 29 : 321-357.
- Taylor L R, Woiwod I P and Perry J N 1978 The density dependence of spatial behaviour and the rarity of randomness. *Journal of Animal Ecology* 47 : 383-406.
- Trumble J T 1982 Temporal occurrence, sampling and within field distribution of aphids on broccoli in coastal California. *Journal of Economic Entomology* 75(2): 378-382.
- Walgenbach J F, Wyman J A and Hogg D B 1985 Evaluation of sampling methods and development of sequential sampling plan for potato leaf hopper on potato. *Environmental Entomology* 14 : 231-236.

195
Acc. No: D. 4135
Date: 20.4.93

Watanabe T 1927 A control method for Hellula undalis Fab. (Pyralidae) a pest of vegetables (In Japanese) Agriculture and Horticulture ii 9 : 987-992.

Wilson L T, Picker C Mount R C and Zalom F G 1983 Presence - Absence sequential sampling for cabbage aphid and Green peach aphid (Homoptera : Aphididae) on Brussel Sprouts. Journal of Economic Entomology 76(3) : 476-479.

Yadav P R, Yadav L S and Dashad S S 1988 Comparative efficacy of some insecticides against the aphid, Lipaphis erysimi Kalt. on cabbage crop. Indian Journal of Entomology 50(1): 61-68.

*Yamada H 1981 Seasonal life history of cabbage web worm Hellula undalis F. Bulletin of the Vegetable and Ornamental Crops Research Station, Japan 8 : 131-141.

*Original not seen

...