Effects of intercropping Cabbage with Alliums and Tomato, on the incidence of the Diamondback moth, *Plutella xylostella* (L.)

By

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A Dissertation submitted to the University of Zambia in partial fulfilment of the Requirement for the degree of Master of Science in Agronomy

LUSAKA

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APPROVAL PAGE

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ABSTRACT

In assessing the efficacy and economic value of intercropping cabbage as a way of managing Diamondback moth (DBM), *Plutella xylostella* L., six cropping cultures were evaluated. The trial was conducted at the National Irrigation Research Station, in Mazabuka, Zambia, in 1995/96. The cropping cultures consisted of cabbage monocrop and five other crop combinations. These were cabbage + garlic, cabbage + leek, cabbage + onion, cabbage + shallots and cabbage + tomato. Cabbage monocrop had a significantly ($P>0.05$) higher incidence of DBM immatures in the early growth stage (3^{rd} and 4^{th} weeks after transplanting), than garlic, leek and tomato. There were, however, no significant differences ($P>0.05$) in the incidence of the pest in subsequent weeks of sampling and in its overall incidence for the whole sampling period. Cabbage monocrop recorded significantly ($P<0.05$) higher overall leaf damage index (%) for the whole sampling period than leek, shallots and tomato, though weekly observations were not significant ($P>0.05$). Observed treatment differences for the cabbage mean total yields (t/ha) and cabbage mean marketable yields (t/ha) were insignificant ($P>0.05$). Cabbage monocrop, however, had significantly ($P<0.05$) higher percentage yield loss associated with pest leaf damage than other treatments, except for cabbage intercropped with onion. *Cotesia plutellae* Kurdjumov, a parasitoid, of DBM larva was found to occur in all the six cropping cultures. There were no significant differences ($P>0.05$) in the incidence of the parasitoid between the six cropping cultures. Actual parasitism levels of DBM larvae by the parasitoid were also insignificant ($P>0.05$). Overall, the simple linear Correlation Coefficient ($r = + 0.87$) between mean parasitoid cacoons and DBM larvae was significant ($P<0.05$). There was thus a positive linear relationship between the overall mean number of parasitoid cacoons and the overall mean number of DBM larvae. The simple linear Correlation Coefficient ($r = + 0.96$), between overall DBM larvae incidence and overall leaf damage was significant ($P<0.05$). A positive linear relationship between the parasitoid and the pest was thus confirmed. In terms of profitability, the cabbage + leek combination had the highest positive net returns of + K 11 757 600 00, while the cabbage + tomato combination had the lowest negative net returns (- K 3 059 576 00).

DEDICATION

To my late father, W.H. Luchen, my mother Sarah, M. Luchen and my dear wife Cecelia for the unique role each one of them played in making me what I'm.

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TABLE OF CONTENTS

PAGE

LIST OF TABLES

PAGE

LIST OF FIGURES

LIST OF APPENDICES

1. INTRODUCTION

Cabbage, *Brassica oleracea* var. *capitata* (L.), an important vegetable crop in Zambia, experiences severe pest attacks in summer (hot dry season). As a crop, cabbage ranks among the three most widely cultivated exotic vegetables by small-holder farmers in the three agro - ecological regions of the country (AVRDC, 1997). It has , however, been observed that, the high pest load, coupled with unfavourably high temperatures, results in reduced production of the crop (Mingochi et al., 1995). The Diamondback moth, *Plutella xylostella* (L.), is the most serious pest of cabbage in the summer. Damage by the pest causes qualitative and quantitative losses in cabbage yields (MAWD, 1984; IPM Horticulture, 1995a; Mingochi et al., 1995). Up to hundred percent loss in yield can result from a severe attack by Diamondback moth (DBM), on cabbage (Iman et al., 1986). The moth is recognised as a major pest of Brassicas in the Eastern and Southern African region (IPM Horticulture, 1995b).

Diamondback moth damage to Brassicas is by the larval stage of the pest (Chelliah and Srinivasan, 1986). An attack in the seedling stage of the cabbage, could result in the destruction of the entire crop (Ooi,1986). DBM larvae prefers to feed on younger cabbage leaves in the middle and inner portions of the plant (Ooi, 1986). The destruction of the plant's apical bud, may induce formation of multiheads. Often, the mother plant fails to sustain the multiheads, an aspect that results in the failure of leaf folding and the inability to form normal heads. The pest can reduce the photosynthetic capacity of both young and old plants through defoliation or perforation. After head formation by the plant, DBM larvae can cause serious losses in the marketable quality of the cabbage by boring into the head (Ooi,1979). In hot and humid weather, larval damage to cabbage tissue probably pre-disposes the plant to infection by fungal and bacterial diseases such as Soft rot (*Erwinia crotovora*).

A range of commercial pesticides have been evaluated and recommended for the control of DBM in Zambia (Jensen, 1986; MAWD, 1986). Preliminary studies on the use of biological control methods against the pest were also carried out in the past, though success appears to have been limited (Mingochi et al.,1995). However, complete reliance on commercial insecticides to control this pest is likely to be unsustainable in the long run. The cost of the recommended pesticides is unaffordable to the majority of small and medium scale vegetable growers. There have also been persistent complaints by farmers on the low efficacy of the commonly used insecticides like, Dimethoate, Karate (Lambdacyhalothrin) and Fastac (Cypermethrin) in controlling DBM (ESZ, 1994). Low efficacy of the pesticides has raised speculation about possible development of resistance by the pest (IPM Horticulture, 1995b; MAFF, 1995;1996). Although the suspicions are as yet unverified, DBM resistance to pesticides has been observed in many places around the world. Occurrence of resistance has been common wherever attempts to control it had involved excessive use of insecticides (Leibee and Savage, 1992; Syed, 1992; Talekar and Shelton, 1993)..

With the above limitations of the chemical control method in managing DBM in Zambia, exploration of alternatives becomes imperative. Such alternatives should incorporate simplicity of application and effectiveness against the pest. The method should also be economical and sustainable from the farmer and the environment protection perspective.

Intercropping of cabbage with other crops could be an effective method of managing DBM in cabbage. Some plant species, are reported to either repel or make host finding difficult for the pest when intercropped with cabbage (Waage, 1990). Tomato used as an intercrop, is said to emit volatile compounds from its leaves, and these repel the adult DBM from laying eggs on cabbage (Srinivasan and Veerish, 1986). Similarly, the aromatic scent of Alliums has been reported to repel DBM (Talekar et al., 1986; Messiaen, 1992).

Parasitoids could be important in DBM management. Verification of their occurrence, identity and how changes in the usual cropping system might possibly affect them needs to be ascertained. Identification of the parasitoid species present in the intercropping eco-system is necessary for their eventual inclusion into a unified DBM management program.

Taking into account the above considerations on the DBM problem, a preliminary evaluation of the potential of some crops in suppressing DBM when intercropped with cabbage was undertaken. Crops included for intercropping in this study were; Garlic, *Allium sativum* (L.); Leek, *Allium porrum* (L.); Onion, *Allium cepa* (L.); Shallots, *Allium aggregatum* (L.) and Tomato, *Lycopersicum esculentum* (Miller.). Intercropping essentially meant the sacrificing of some land otherwise meant for cabbage production to the intercrop. From a physical yield perspective, this loss in land or cabbage production space would be compensated for by the resulting yield from the intercrop. In economic terms, the benefit from the opportunity cost could be measured by the reduction in cabbage yield losses due to DBM damage. The other contribution would be the monetary value of the cash sales from the intercrop itself.

To optimisation of yields from both the cabbage and the intercrop was necessary. Under the modified growing environment, the study therefore, tried to adhere as much as possible to the recommended husbandry practices for growing specific vegetables. Thus, even though standardisation is an important pre-requisite in experimentation, its implementation becomes difficult in this type of study. By necessity, each of the different vegetable crop species used has different propagational, nutritional and other agronomic requirements. It was not therefore possible to have a standard approach to raising seedlings, fertiliser application, pest control practices and harvesting regime. For instance, there was no logic in spraying all crops with a particular pesticide when one specific crop in the study was seriously attacked by a given pest or disease. Such an approach may have resulted in phytotoxicity on the other crops for which the pesticide is not recommended.

The intercrop vegetables in this study were chosen on the bases of their wide cultivation among small-holder farmers in the country. The possible success of these crops in ensuring profit and reducing damage by DBM in cabbage was expected to stimulate adoption of the intercropping practice by the target farmers. Cultivars of cabbage, leek, onion and tomato used in the study were those that are currently recommended by the Ministry of Agriculture, Food and Fisheries in Zambia. They are specifically suited for production during the hot-dry season and hot-wet seasons, due to their tolerance to high temperatures. Local accessions of garlic and shallots used were also selected due to their wide cultivation in most parts of the country. The study was thus, specifically targeted at small-scale vegetable growers with the following objectives:

i) To determine the effects of intercropping cabbage with selected crops on the incidence and damage severity of DBM.

ii) To determine the incidences of natural enemies (Parasitoids) of the DBM in the intercropped cabbage plots.

iii) To determine the economic potential or profitability of cabbage intercropping.

2. HYPOTHESES

The underlying hypotheses for the study were that:

i) There are no significant differences in the incidences of, and damage severity of DBM in cabbage intercropped with selected crops.

ii) There are no significant differences in the incidence of natural enemies (parasitoids) of the DBM in cabbage plots intercropped with selected crops.

3. LITERATURE REVIEW

The Diamondback moth is described as a pest with a wide range of hosts in both crucifers and non- cruciferous crops (Koshihara, 1986; Chelliah and Srinivasan, 1986). It is universally distributed and occurs wherever crucifers are grown in the world (Talekar and Shelton, 1993). Within the diversity of cruciferous food plants, DBM has been observed to have higher preference for cabbage and cauliflower (Chelliah and Srinivasan, 1986).

Population studies on the incidences of DBM in its habitat, presents rather diverse findings. Ecological studies at one site in Malaysia revealed a mean population density ranging from 2 to 78 larvae per cabbage plant (Ooi, 1979). At another site, however, the mean DBM incidence was 160 larvae/plant (Ooi, 1979). Means of 14.0 to 16.7 DBM larvae/plant have also been recorded in Japan (Koshihara, 1986). At the peak of an outbreak in Malaysia, a mean of 447 DBM larvae/plant were reported (Wan, 1970).

In evaluating the effects of tomato and cabbage intercropping, on the incidence of DBM, monocrop cabbage recorded mean DBM larvae numbers of between 2.0 and 7.1/cabbage plant (Bach and Tabashnik, 1990). Other related studies by Srinivasan and Veeresh, (1986) recorded a range of 2.2 to 2.4 and larvae/plant in cabbage intercropped with tomato. In the same study, monocrop cabbage recorded 2.3 to 5.3 larvae/plant. These pest densities were, however, considered too low for drawing of meaningful conclusions. on the effects of intercropping on the pest. The underlying factor being that DBM tends to aggregate on single plants. Single plants could thus have a high inflatory influence on the observed overall populations even when the pest is not wide spread in a given crop habitat. There is no information on the population densities of DBM on crops in Zambia. Further, no research has been done on either the population dynamics or economic thresholds of the pest on vegetable crops. Elsewhere in the world, there are highly varied findings on what is considered the economic threshold levels for the pest. Despite differences of opinion on the suggested threshold levels, the crop growth stage is seen to be a major determining factor of the parameter (Sastrodihardjo, 1986). In India, a threshold level of 1 larva/cabbage plant before the 10 leaf stage and 2 larvae/plant there after, has gained recognition (Chen and Su, 1986). Prasad (1963), observed that seven weeks after transplanting , cabbage could sustain of 20 DBM larvae /plant before significant economic injury and yield reduction were detected . An economic threshold of 10 and 20 second and third instar larvae/plant up to one month and between one and two months rspectively from transplanting has also been suggested. Magallona (1986), found the economic threshold at 1 larva/plant, without specifying the growth stage of the cabbage crop. Sastrosiswojo (1994), on the other hand suggested an economic threshold of 0.5/larvae/plant. An even lower economic threshold level of 0.1 larva/plant, has been reported in Indonesia (Iman et al.,1986). Such low threshold levels would however, present practical problems, especially considering that DBM populations are in most cases aggregated. A single cabbage plant that is highly infested with DBM larvae would thus exert considerable influence on what is considered the economic threshold, even when the rest of the crop is relatively pest free. In reality, the severe damage inflicted by a very high DBM population on one plant cannot, possibly contribute so much to the overall economic damage of the entire crop with low infestation. Some researchers thus suggest the use of economic threshold levels based on the percentage of plants that record DBM larvae infestation. The actual numbers of larvae present on the plant are disregarded. An economic threshold level of 10% infested plants before head formation and greater than 20 % after head formation has been suggested (MSU, 1997).

Literature is scanty on how DBM leaf damage during the growth stage of a plant is reflected in the final yield of the crop. Lim et al., (1986), reported that a 10% and 20% leaf damage caused by DBM would correspond to a 20% and 50% yield loss reductions, respectively. Due to pest complexes that often occur in the field, it is difficult to proportion the leaf damage attributed to DBM.

Among defoliating insect pests, lower population densities occur in diverse habitats, compared with simple habitats comprising host plants only (Bach and Tabashnik,,1990; Andow, 1988). Lower population densities of DBM have thus, been seen to occur in more polycultures than in monocultures (Buranday and Raros, 1973;Talekar et al., 1986). Although this view is widely accepted, conflicting findings by Horn (1987), suggest that parasitism rates can in fact be equally low in diverse habitats as in monocultures.

Lowering of DBM incidence through intercropping cabbage with tomato has been reported by a number of researchers (Srinivasan and Veeresh, 1986; Bach and Tabashnik, 1990; Madriaga, 1994). However, in all these studies, the presence of the tomato plants could not prevent early season damage by the pest (Bach and Tabashnik, 1990). It was further observed that the tomato intercrop did not necessarily maintain the marketable yield of the cabbage (Madriaga, 1994).

The suppressing effect of tomato and garlic on DBM density in a crop field was also reported in a cabbage intercropping experiment in Taiwan (Talekar et al., 1986). In the experiment, leek and shallots intercropped with cabbage had no effect on the incidence of the pest. Observed treatment differences were, however not significant due to the wide variation among replicates. The phenological age of transplanting the cabbage or the intercrop into the cropping culture plays a role in the success or failure of the intercrop in reducing DBM incidence. Srinivasan and Veeresh (1986), reported a slight reduction of DBM larval incidence when cabbage was planted 15 days later than the tomato intercrop. Maximum reductions were recorded, when the cabbage was planted 30 days later than tomato. Volatile compounds that are emitted from the tomato leaves to deter oviposition by DBM is thus at the maximum from 30 to 35 days after transplanting (Srinivasan and Veeresh, 1986).

The role natural enemies play in the population dynamics of DBM has been acknowledged by many researchers (Lim, 1986; Lim et al., 1986; Talekar and Shelton, 1993). The absence of effective natural enemies, especially parasitoids, is believed to be the major cause of increased DBM`s pest status in most parts of the world (Talekar and Shelton, 1993). Accurate measurement of parasitoid impact on the pest is vital if they are to be integrated into DBM management cropping practices (Waage and Cherry, 1992). A preliminary step in the exploitation of parasitoids is to ensure that they are correctly identified . However, most existing literature on DBM parasitoid taxonomy has many misidentifications (Greathead et al., 1990; Fitton and Walker, 1992).

Previous studies have revealed the existence of numerous natural enemies of DBM. In spite of this, only a few species belonging to the genera *Diadegma* (Hymenoptera: Ichneumonidae), *Cotesia; Apanteles* (Hymenoptera: Braconidae) and *Microplitis*, are important (Lim, 1986; Talekar and Shelton, 1993). Except for *D. eucerophaga* Horstmann and possibly *D. fenestrale* Holingren, none appears capable of exerting full control alone (Lim, 1986). It would appear that a combination of these parasitoids could be more effective. Successful establishment of particular parasitoid species in any area, is however linked to environmental conditions (Talekar and Shelton, 1993). In the lowland areas of the tropics and sub-tropics, where temperatures are high, *Cotesia plutellae* Kurdjumov is said to be the only larval parasitoid that can survive (Talekar and Shelton, 1993). A number of findings, however, reveal the limited success of *Cotesia plutellae* in controlling DBM.

In Zambia, a combination of *Cotesia plutellae, Thyrella collaris* Kurdjumov and the endemic *Tetrastichus sokolowiskii* Kurdjumov reportedly provided up to 80% reduction of DBM damage in cabbage (Yaseen, 1978). The historical background of these parasitoids and their performance in the sites of introduction is rather obscure. Some findings suggest the release of these parastoids in the early 80's (MAWD, 1982; Mingochi et al., 1995). Greathead et al., (1990) on the other hand asserts that established populations of these parasitoids were already in existence as far back as 1971. The overall performance of the parasitoids in controlling DBM has had rather contrasting assessments. Yaseen, (1978) reported a reduction in DBM damage as a result of the parasitoid introductions at a site in Mumbwa. MAWD, (1981) to the contrary observed that the pest continued to cause serious damage in cabbage, despite the release of the parasitoids in the same area.

According to Lim et al., (1986), problems with DBM occur where there is absence or low levels of parasitisation of the pest, i.e. not exceeding 36%. The situation often arises where a natural enemy vacuum is created by excessive insecticide use (Sastrosiswojo and Sastrodihardjo, 1986). It can also occur when there is a lack of host and parasitoid habitat continuity (Sastrosiswojo and Sastrodihardjo, 1986). Sustainable management of DBM has some prerequisites. The suppressing effect of the natural enemies on the pest needs to be complimented by favourable cropping practices and the judicious use of pesticides (Waage and Cherry, 1992). Excessive pesticide usage is likely to have a more unfavourable impact on natural enemies populations than on the population of the pest. The logic being that the natural enemies have a slower multiplication rate than the pest. In field situations, the parasitoid *Cotesia plutellae*'s numerical responsiveness to increasing DBM populations has been acknowledged (Alam, 1992). Equally, its inability to reduce the pest population is also noted in a number of studies (Alam,1992). Further more, it has been suggested that high rates of parasitism alone cannot, always be directly correlated with the success or failure of DBM control (Sastrosiswojo and Sastrodihardjo, 1986). Rates of parasitism for the parasitoid rarely exceed 60% (Ooi, 1992), though rates of up to 88.7% have been observed (Alam,1992; Morallo-Rejesus and Sayaboc,1992; Waterhouse, 1992). Of importance, in the parasitism rates of *Cotesia plutellae* is the phenological age of the cabbage crop from transplanting . In one study, higher parasitism rates were recorded soon after cabbage transplanting, but later decreased as the plants grew older (Talekar and Yang, 1993). The explanation for such a trend may be that the searching ability of the parasitoid for DBM larvae probably becomes restricted by the increased foliage in older cabbage plants. The outcome in this study was that, intercropped and monocropped cabbage did not however, indicate significant differences in parasitism rates (Talekar and Yang, 1993).

Apart from parasitoids, DBM is reported to suffer mortality from predation by Lady bird beetles and other predators (Riggin-Bucci and Gould, 1997). *Plutella xylostella* is also known to be infected in nature by several pathogens, including entomphthoraceous fungi, bacteria and viruses (Wilding, 1986). Information is currently lacking on their overall contribution to DBM suppression in vegetable crops in Zambia. This may be attributed to the lack of expertise and equipment needed to carry out such studies by field Researchers.

4. MATERIALS AND METHODS

The trial was conducted from October, 1995 to February, 1996 at the National Irrigation Research Station (N.I.R.S.), in Mazabuka. The N.I.R.S. lies at an altitude of 978 M above sea level and is on latitude 15° 46' south and longitude 27° 55' east. Brassicas crops, had not been planted on the trial site in the two preceding seasons. A minimum of 200 m was left between the trial site and the nearest Brassica crop. Prevailing weather conditions changed from being initially hot and dry to being hot and humid (Appendix 1).

The trial consisted of 6 treatments, each replicated 3 times as follows:

1. Cabbage monocrop
2. Cabbage intercropped with garlic i.e. cabbage + garlic
3. Cabbage intercropped with leek i.e. cabbage + leek
4. Cabbage intercropped with onion i.e. cabbage + onion
5. Cabbage intercropped with shallots i.e. cabbage + shallots
6. Cabbage intercropped with tomato i.e. cabbage + tomato

Cabbage ((Cultivar (Cv) `Riana F1`)) and tomato (Cv `Money maker`) seedlings were raised in compost modules in a nursery 160 m away from the study site. The method of raising the seedlings was used because of its ability to ensure uniformity of the seedlings at transplanting. It was considered compatible with the existing approach by many small-scale peri-urban gardeners in Zambia, who buy seedlings raised in this way from commercial nurseries. Seedlings of onion (Cv `Texas early grano`) and leek (Cv `Indian River`), were raised in nursery beds (as is often practiced by farmers) for six weeks before they were transplanted to the field. Local accessions of garlic and shallots setts, were first sprouted and then directly planted from the pre-sprouted setts. Choice of cultivars and nursery management followed existing country recommendations (Mingochi and Luchen, 1993). The selected cultivars of cabbage, tomato, leek and onion were heat tolerant. Seedlings were watered once in two days due to the hot weather. Six days before transplanting, all seedlings had to be hardened. Hardening of seedlings involved reduction of irrigation from once in two days watering to once in three days. All the intercrops were transplanted, two weeks before transplanting the cabbage.

The trial was set in a Randomised Complete Block Design (RCBD) with 3 replications. The gross plot size was 5 m x 5 m = 25 m^2, and consisted of single alternating rows of cabbage and the intercrop. The net plot size was 12.5 m^2. Inter-row spacing was 50 cm, while intra-row spacings were 50 cm for cabbage, 30 cm for tomato, and 10 cm for garlic, leek, onion and shallots. Inter-block distance was 2 m, while that between plots was 1 m. Non-experimental factors were: Irrigation, fertiliser level and specific field management practice. Among these were the method of raising seedlings, timing of fertiliser applications, staking and pruning in tomato.

4.1 FIELD MANAGEMENT

The land was ploughed, disced and irrigated to field capacity. The cabbage and intercrop seedlings were planted on small ridges 10 cm high and 25 cm wide. Recommended management practices for each of the various crops was followed in both the nursery and field (VRT Project outline 1983/84). All treatments had to be weeded and irrigated at the same time. In the field, crops were irrigated only by furrow, because overhead irrigation has been reported to suppress DBM populations (Talekar et al.,1986). Throughout the growing period, a seven days irrigation interval was observed. No irrigation was however, applied if it had rained within the seven days period and in such a case, the next day of irrigation had to be adjusted accordingly. To keep up with existing recommendations, tomato was staked with wooden sticks, two weeks after transplanting, so as to enable plants to grow up-right and to avoid contamination of leaves and fruits by soil borne diseases. The tomato was also hand pruned four weeks after transplanting to promote normal fruit formation.

Fertiliser was applied according to the existing country recommendations (VRT Project outline,1983/84). For both the cabbage and the intercrops, basal dressing was applied at the rate of 800 Kg/ha of D compound (N P K, 10:20:10) at transplanting. The fertiliser was applied in the furrows. Ammonium nitrate (34% N), was applied as top dressing at the rate of 200 Kg/ha. Cabbage received a single top dressing application, 3 weeks after transplanting. Tomato was given a split application of the top dressing at 3 and 6 weeks from transplanting. The application schedule followed existing country recommendations. Garlic, onion, leek and shallots were given single applications, 4 weeks after transplanting.

4.2 CROP PROTECTION

All plots were kept free of weeds. Weeding was carried out using a hand hoe as need arose in the third, seventh and tenth weeks from transplanting. Though the cabbage crop was attacked by Harlequin bugs (*Bagrada* spp) and some defoliating pests, pesticides were not applied to control them. The damage from these pests appeared rather marginal, with only a few plants experiencing light blemishing on the lower leaves. Red spider mites (*Tetranychus* spp) infested the tomato in the seventh week from transplanting. Infestation by Red spider mites at this time of the year and at such a growth stage could result in the total destruction of the crop. Thus it became necessary to institute some intervention through a single spot application of Tik Tok (Dicofol) an acaricide recommended for use in tomato. A conical plastic hood was attached to the knapsack sprayer lance in order to improve targeting of the spray on to the tomato plants and to reduce drift to cabbage plants. Aphids on cabbage were effectively controlled by a single application of Pirimor (Primacarb) an aphicide, in the fifth week after transplanting. Alternaria leaf spot, *Alternaria solani*, which attacked tomato in the 9^{th} week from transplanting, could not effectively be controlled by 3 weekly applications of the fungicide Dithane M45 (Mancozeb). The disease severely affected the tomato crop especially during the fruit setting period. No major DBM oviposition or behavioural changes were expected to have occurred from these pesticide sprays, such as to influence its larval densities. The precision of application and the specificity of their mode of action on target pests or diseases would have highly minimised their effect on DBM.

4.3 HARVESTING

In order to ascertain the compatibility of cabbage and a particular intercrop vegetable, it was necessary to assess plant vigour. Crop species that are incompatible as a result of competition usually grow with low vigour. The vigour of the cabbage and intercrop were thus visually assessed in the mid growth stage (7th week from transplanting). For the final growth stage (12th week from transplanting), another assessment based on measurement of canopy width (VRT Project outlines, 1983/84) using a ruler was carried out. From the final assessment, a vigour ranking scale specific to each crop was established. A non standardised scale was inevitable, since the different crop species in the study have different canopy sizes. Vigour was ranked as very low, low, moderate and high. For cabbage plants, canopy widths were ranked as follows; less than 10 cm = very low, 10 cm to less than 20 cm = low, 21 cm to less than 30 cm = moderate and 30 cm and above = high. Onion, garlic and leek which tend to have a similar canopy spread were ranked as follows; less than 10 cm = very low, 10 cm to less than 15 cm = low, 15 cm to less than 20 cm = moderate and 20 cm and above = high. The scale for tomato was, less than 15 cm = very low, 15 cm to less than 20 cm = low, 20 cm to less than 25 cm = moderate and 25 cm and above = high. Using the approach, the final category ranking which was determined on the basis of the average canopy width for the plot. Individual crops used in the study were harvested at a specific time of attaining maturity. Repetitive harvests were necessary for the tomato crop in line with its character of maturity. Tomato intercrop yield records were taken at each harvest. As is commonly practiced by most fresh market gardeners in Zambia, only single harvests were necessary for the other vegetable crops used in the study other than tomato. Due to the inherent variation in maturity duration within a cultivar, even for a crop that was planted at the same time maturity standards based on the percentage of mature plants are often used. Cabbage, garlic, leek, onion and shallots were each harvested upon attainment of 75% maturity based on individual plant maturity counts. Maturity of onion and garlic was said to have been attained when tops fell. For leek and shallots maturity was arrived at when mid leaves started drooping. A cabbage plant was considered mature when the top of the plant became completely overlapped by the last folding leaf of the head. Data for assessment of economic potential or profitability was taken from the 5 inner rows of cabbage monocrop (net plot size). In the case of the other treatments, 3 inner rows of cabbage and 2 inner rows of the intercrop were the ones that were considered. Thus it was possible to work on the same unit area of five rows for all treatments, despite differences in the cropping pattern. A total of 50 cabbage plants were to contribute to the yields in each plot for cabbage monocrop. During the final stand count done at harvest it was found that all cabbage plants were alive except in the 3rd replicate where two plants had died, leaving only 48 plants alive. In the tomato intercrop, a total of 32 tomato plants were to contribute to the final yields and all of them had survived up to the final stand count at harvest. Garlic, leek, onion and shallots were supposed to have a total of 100 plants as intercrops/plot. At the final stand count of the garlic all plants were alive except in the 2nd replicate where 3 had died. No plants were found to have died in leek and shallots at the final stand count. Cabbage heads for each plot were harvested by cutting with a knife and weighed to get the gross yields. The pest damaged leaves characterized by a skeletonised cuticle were removed using a knife and the heads were then re-weighed to determine the marketable yield. The loss in yield was calculated from the difference between the total yield and the marketable yield.

4.4 PEST INCIDENCE

Observations of the incidences of DBM, other pests, parasitoids and yield were made from the 3 inner rows of cabbage/plot. Weekly scoring for DBM immatures (larvae + pupae), on cabbage plants commenced two weeks from the time cabbage was transplanted to the field. In each plot, 10 cabbage plants were randomly selected from the 3 inner rows. Each of the cabbage plants in the 3 rows was assigned a number from 1 to 30. At each sampling, a table of random numbers was used to randomly select cabbage plants on which insect counts were made. All unfolded leaves from the selected cabbage plants were physically inspected at each sampling date. The number of DBM larvae and pupae present on each plant were then recorded. The insect larvae were left undisturbed on the plant, except for the 3 larvae that were to be artificially reared to assess parasitism. With this largely non-destructive weekly sampling method on the pest, no major effects on DBM immatures densities would have been expected. It could however, still be argued that the removal of the 3 larvae for rearing may have slightly contributed to a reduction in the pest populations. No information was available on the longevity of various DBM instar and pupal development stages in Zambia. The sampling period covered 9 weeks. Weekly plot means were calculated. Observations on the incidence of other pests were concurrently undertaken using the protocol outlined for DBM. The economic potential or profitability of each of the treatments was calculated by simple gross margins. Variable costs of production were subtracted from the combined cash value of cabbage and the intercrop or that of cabbage monocrop. Net returns were calculated as the positive or negative cash benefit above or below returns from cabbage monocrop based on equivalent area. The gross margin analysis and net returns were first calculated on the basis of the original plot size (Appendix 8), before conversion to standard per hectare basis.

4.5 DAMAGE ASSESSMENT

Leaf damage was assessed weekly on the 10 randomly sampled cabbage plants/plot. Assessment of injury by the pest was based on damage index% (Williams, 1966). The damage index employed was a slight modification of that suggested by Lim et al., (1986).

$$\text{Damage index (\%)} = \frac{(N0 \times 4) + (N1 \times 20) + (N2 \times 50) + (N3 \times 100) \times 100}{N0 + 1 + 2 + 3}$$

Where N0 = Number of plants with score `0` (4% or less damage)

N1 = Number of plants with score `1` (5% to 20% damage)

N2 = Number of plants with score `2` (21% to 50% damage)

N3 = Number of plants with score `3` (51% to 100% damage)

4.6 DIAMONDBACK MOTH PARASITISM

To determine the incidence of DBM parasitoids in the cabbage crop for the various cropping systems, parasitoid cacoons present per plant were recorded during weekly sampling. The parasitoid counts were from each of the 10 cabbage plants randomly selected in the scouting for DBM. Parasitoid cacoons were left undisturbed on the cabbage plants after counting in order not to disrupt the populations. Weekly means were then calculated. To determine the level of parasitism, initially a total of 10 DBM larvae were to be collected/plot for artificial rearing in breeding jars. However, this number had to be reduced to 3 larvae/plot, due to the low incidence of the pest. For rearing purposes, only 2^{nd} to 4^{th} instar larvae were collected, as other instar stages are not usually parasitised by *Cotesia plutellae*. The larvae were fed on fresh cabbage leaves from a few cabbage plants raised in a glasshouse a few hundred metres away from the field. Raising of these plants in a glasshouse was done in order to avoid their possible colonisation with DBM, other pests or parasitoids. At each feeding, the cabbage leaves were carefully inspected to ensure that there were no eggs, larvae or cacoons of DBM, parasitoids or any other insects. The DBM larvae were kept in the jars until either the parasitoid or the adult host emerged. Emerged parasitoids for each plot were preserved in 80% alcohol and later sent for identification to the Natural History Museum in the United Kingdom and the Plant Protection Research Institute in South Africa. The number of emerged parasitoids in comparison to the number of larvae reared/plot was then used for the determination of the percentage parasitism levels. The approach is in accordance with the procedure suggested by Waage and Cherry, (1992). The method however, tends to inflate the parasitism estimate at low host populations (Waage and Cherry, 1992).

4.7 STATISTICAL ANALYSIS

Data on total and marketable yields of cabbage were analysed by ANOVA. F- test was used to determine whether there were significant differences between treatments. Mean yield effects were separated by the Least Significant Difference (LSD). Original data (Appendix 9) on percent yield loss of cabbage was transformed by the Arc-sine (Table 7) before performing ANOVA. The LSD was used to separate treatment means (Gomez and Gomez, 1984).

Individual weekly ANOVAs for DBM incidence, parasitoid incidence, parasitism rates and leaf damage index (%), were computed followed by pooled ANOVAs. Chi-square to test for homogeneity of variance was applied to data on DBM incidence, parasitoid incidence, oriental cabbage worm incidence and leaf damage index (%). Original data (Appendix 2, 3, 4, 5 and 6) were transformed (Table 1, 2,3, 4 and 8) to determine the existence of significant differences between treatments at the same and different sampling dates. Verification of the interaction effect between treatment and time of sampling was in addition undertaken. LSD was used to separate the sampling date means for each treatment in trend comparisons (Gomez and Gomez 1984).

Simple linear coefficient of correlation was used to determine the existence of a possible relationship between pest incidence (DBM and Oriental Cabbage worm) and leaf damage index. The parameter was further used to determine the existence of a possible relationship between DBM incidence and *Cotesia plutellae*.

5. RESULTS

5.1 DIAMONDBACK MOTH INCIDENCE

The pooled ANOVA, indicated no significant differences ($P>0.05$) in the mean number of DBM immatures (overall), between treatment means for the whole sampling period. However, mean weekly differences obtained in the 3rd and 4th weeks after transplanting were significant at the same probability level (Table 1). The interaction between treatment and sampling date was significant ($P<0.05$). In the 3rd and 4th weeks after transplanting, cabbage monocrop had a

Table 1: Mean number of Diamondback moth larvae and pupae recorded/cabbage plant/plot during weekly sampling (Transformation: Log (X + 1)) in the intercropping study at the National Irrigation Research Station in Zambia from October to December, 1995.

Weeks after transplanting (Sampling date) Treatment	3	4	5	6	7	8	9	10	11	Overall mean (original data)
				Mean number of DBM immatures						
Cabbage monocrop	0.55 a	0.36 a	0.50 a	0.42 a	0.11 a	0.27 a	0.18 a	0.16 a	0.16 a	.1.14 a
Cabbage + Garlic	0.25 b	0.26 b	0.64 a	0.51 a	0.15 a	0.14 a	0.18 a	0.31 a	0.22 a	1.10 a
Cabbage + Leek	0.30 b	0.11 c	0.45 a	0.40 a	0.17 a	0.21 a	0.19 a	0.27 a	0.27 a	0.85 a
Cabbage + Onion	0.42 ab	0.34 ad	0.69 a	0.55 a	0.19 a	0.17 a	0.29 a	0.29 a	0.24 a	1.37 a
Cabbage + Shallots	0.37 ab	0.33 ad	0.48 a	0.44 a	0.12 a	0.13 a	0.25 a	0.27 a	0.23 a	0.91 a
Cabbage + Tomato	0.23 b	0.22 b	0.58 a	0.30 a	0.03 a	0.13 a	0.22 a	0.15 a	0.26 a	0.75 a
Grand mean	0.35	0.28	0.56	0.44	0.13	0.18	0.22	0.24	0.22	
$LSD_{0.05}$	0.23	0.10	ns	ns	ns	ns	ns	ns	ns	ns
S.E	0.07	0.05	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.2
C.V%	34.94	33.32	30.20	23.06	57.08	63.33	23.98	35.05	33.72	24.21

Means in the same column followed by the same letter are not significantly different (P>0.05) according to the LSD test.
ns= F value is not significant at the given probability level

significantly higher mean number of DBM immatures (larvae + pupae)/plant than other treatments, except onion (Table 1). The remainder of the sampling period from the 5th to the 11th week after transplanting, indicated no significant differences(P>0.05) between treatments in the mean number of DBM immatures. Seasonal trends showed an initial decline in the incidence of the pest in all treatments from the 3rd week to the 4th week after transplanting, except in cabbage intercropped with onion (Figure 1). The period of decline was followed by a steep increase in the incidence of DBM in the 5th week in all treatments, except in cabbage monorop. In the case of cabbage monocrop, a further decrease in the pest was observed. A general decline of DBM was evident in all treatments starting around the 6th week.

The initial sampling date (3rd week after transplanting), in cabbage monocrop indicated a significantly (P<0.05) higher incidence of DBM immatures than all dates after the 7th week (Table 2). Differences in the incidence of DBM immatures between sampling dates in cabbage intercropped with garlic and cabbage intercropped with leek were not significant (P>0.05). There was a significantly (P<0.05) higher incidence of the pest in the 5th week than the initial sampling date in cabbage intercropped with onion. For cabbage intercropped with shallots differences between the initial sampling date and other dates were insignificant except for the 7th week (P>0.05). Significantly higher DBM immatures were recorded in the 5th week than in the initial sampling date for cabbage intercropped with tomato (P<0.05).

5.2 INCIDENCE OF OTHER PESTS AND DISEASES

Apart from DBM, there was an infestation of Harlequin bugs, *Bagrada* spp on the cabbage. Oriental cabbage worm, *Hellula undalis* (F.), Cabbage looper, *Trichoplusia* spp and aphids *Myzus persicae* (S.), also affected the crop. The most prominent of these was the Oriental cabbage worm (OCW). There were however, no significant differences (P>0.05) in both the weekly and overall mean number of OCW between the treatments (Table 3). This presented a pest complex. An aphids infestation which occurred in the 5th week after transplanting was timely controlled by a single application of Pirimor (Primacarb). Red spider mites infested the tomato crop, 7 weeks after transplanting. Early blight, *Alternaria solani*, infected the tomato plants 9 weeks after transplanting.

5.3 CABBAGE LEAF DAMAGE INDEX (%)

Pooled ANOVA for leaf damage index (%) for the whole (overall) sampling period, indicated

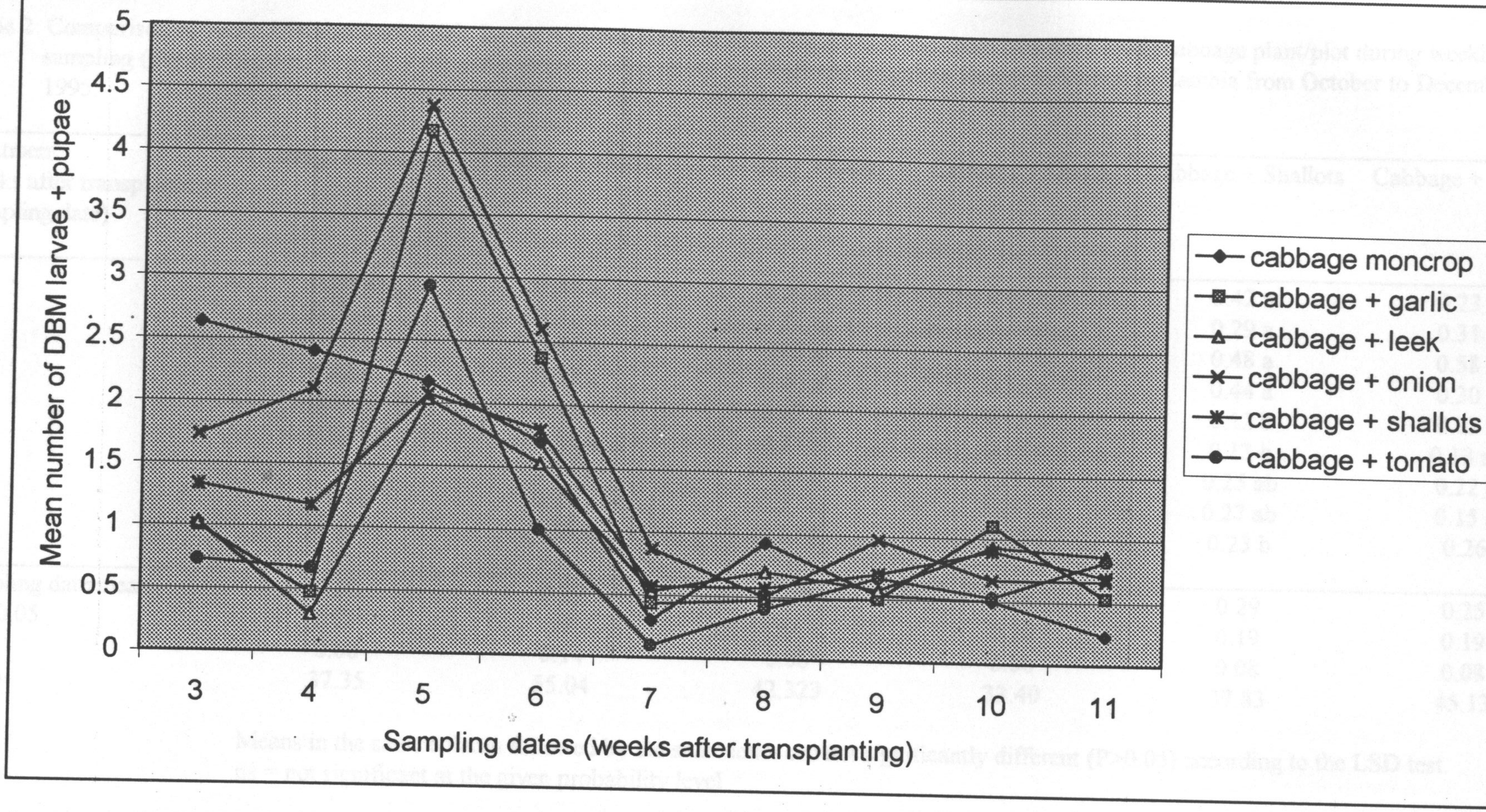

Figure 1: Mean numbers of DBM immatures/plant/plot

Table 2 Comparison of mean Diamondback moth larvae + pupae between sampling dates at the same treatment level /cabbage plant/plot during weekly sampling (Transformation: Log (X + 1)) in the intercropping study the National Irrigation Research Station in Zambia from October to December, 1995.

Treatment Weeks after transplanting (sampling date)	Cabbage monocrop	Cabbage + Garlic	Cabbage + Leek	Cabbage + Onion	Cabbage + Shallots	Cabbage + Tomato
3	0.55 a	0.25 a	0.30 a	0.42 a	0.42 a	0.23 a
4	0.36 a	0.27 a	0.11 a	0.34 a	0.29 a	0.31 a
5	0.50 a	0.64 a	0.45 a	0.69 b	0.48 a	0.58 b
6	0.42 a	0.51 a	0.40 a	0.55 a	0.44 a	0.30 a
7	0.11 a	0.15 a	0.17 a	0.19 c	0.12 b	0.03 c
8	0.27 b	0.14 a	0.21 a	0.17 c	0.13 b	0.13 ac
9	0.18 b	0.18 a	0.19 a	0.29 ac	0.25 ab	0.22 a
10	0.16 b	0.31 a	0.27 a	0.29 ac	0.27 ab	0.15 a
11	0.16 b	0.19.a	0.27 a	0.22 c	0.23 b	0.26
Sampling date mean	0.30	0.29	0.26	0.35	0.29	0.25
LSD0.05	0.20	ns	ns	0.20	0.19	0.19
S.E	0.08	0.14	0.08	0.08	0.08	0.08
CV%	37.35	55.04	42.323	33.40	37.83	45.13

Means in the same column followed by the same letter are not significantly different (P>0.05) according to the LSD test.
ns = not significant at the given probability level

Table 3: Mean weekly number of Oriental Cabbage worm (OCW) larvae/cabbage plant/plot (Transformation: Square Root (X + 0.5)) recorded in the intercropping study at the National Irrigation Research Station in Zambia from October to December, 1995.

Weeks after transplanting (Sampling date) Treatment	3	4	5	6	7	8	9	10	11	Overall mean (original data)
	Mean number of larvae									
Cabbage monocrop	0.73 a	1.10 a	0.80 a	0.80 a	0.93 a	0.77 a	0.83 a	0.73 a	1.10 a	0.27 a
Cabbage + Garlic	0.83 a	0.93 a	0.80 a	0.93 a	1.10 a	0.93 a	0.87 a	0.93 a	0.90 a	0.32 a
Cabbage + Leek	0.73 a	0.90 a	0.70 a	1.00 a	1.17 a	1.03 a	0.73 a	0.87 a	0.93 a	0.30 a
Cabbage + Onion	0.77 a	1.00 a	0.90 a	1.07 a	1.13 a	0.90 a	0.83 a	0.97 a	1.07 a	0.40 a
Cabbage + Shallots	0.80 a	1.00 a	0.90 a	0.87 a	0.90 a	0.90 a	0.87 a	1.07 a	1.07 a	0.35 a
Cabbage + Tomato	0.70 a	1.03 a	0.77 a	0.87 a	1.13	0.90 a	0.87 a	0.97 a	0.83 a	0.33 a
Grand mean	0.76	0.99	0.81	0.92	1.06	0.91	0.83	0.92	0.98	0.38
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
S.E	0.08	0.12	0.08	0.14	0.12	0.08	0.15	0.18	0.12	0.1
C.V%	11.67	14.42	11.62	17.45	13.73	10.6	13.9	23.06	15.2	36.76

Means in the same column followed by the same letter are not significantly different (P>0.05) according to the LSD test.
ns= F value is not significant at the given probability level

significant differences ($P<0.05$) between treatments. The observed differences for weekly means, were however, insignificant at the same probability level (Table 4). Monocrop cabbage recorded significantly ($P<0.05$) higher overall mean leaf damage index (%) than leek, shallots and tomato. There were however, no significant differences in the overall mean leaf damage index (%) between monocrop cabbage and the cabbage +garlic as well as cabbage + onion combination. The interaction effect between treatment and time of observation was insignificant ($P>0.05$). Seasonal trends in the leaf damage index (%) profile indicated a decline from the initial sampling date into the 4th week in all treatments except in cabbage intercropped with onion, (Figure 2). In contrast the leaf damage index profile for cabbage intercropped with onion rise during the same period. The observed decline in leaf damage index (%) up to the 4th week in all other treatments is followed by a steep rise in leaf damage. The exception is cabbage monocrop and cabbage intercropped with leek, in which the downward trend continues into the 5th week. From the 7th week, all treatments experienced a further decrease in leaf damage up to the 10th week, apart from monocrop cabbage where damage started rising again in the 9th week.

The simple linear Correlation Coefficient ($r = +0.96$) between the overall leaf damage index (%) and the overall mean number of DBM immatures/plant/plot was significant ($P<0.05$). On the other hand the simple linear Correlation Coefficient ($r = 0.098$) between overall leaf damage index (%) and the overall mean number of Oriental cabbage worms /plant/plot was insignificant ($P>0.05$).

5.4 GROWTH OF CABBAGE IN ASSOCIATION WITH INTERCROP VEGETABLES

Leek and shallots performed well in both their growth, as well as, yield (Table 5). Based on canopy width, monocrop cabbage and cabbage intercropped with leek grew with high vigour, while cabbage intercropped with garlic and shallots exhibited moderate vigour. The lowest vigour was observed in the cabbage intercropped with tomato (Table 5). There were, however, no significant differences in the average cabbage head weight between all the treatments. Tomato growth vigour was moderate, while garlic exhibited low vigour.

5.5 CABBAGE YIELDS AND LOSSES ASSOCIATED WITH PEST DAMAGE

ANOVA indicated the absence of significant differences between treatments for mean total yield of cabbage ($P>0.05$). Cabbage monocrop gave yields of 34.19 tons/ha, followed by

Table 4: Weekly mean leaf damage index/plot (%) of cabbage plants (Transformation: Arc-sine) recorded in the intercropping study at the National Irrigation Research Station in Zambia from October to December, 1995.

Weeks after transplanting (Sampling date) Treatment	3	4	5	6	7	8	9	10	11	Overall mean leaf damage index (%)
	Mean percentage leaf damage index (%)									
Cabbage monocrop	35.69 a	27.17 a	24.67 a	26.82 a	31.36 a	22.56 a	20.27 a	25.63 a	25.19 a	27.00 a
Cabbage + Garlic	27.61 a	23.45 a	30.55 a	28.90 a	28.46 a	25.56 a	22.70 a	20.73 a	24.80 a	25.87 a
Cabbage + Leek	28.78 a	24.55 a	21.75 a	23.25 a	25.24 a	21.88 a	20.46 a	18.27 a	21.18 a	22.82 b
Cabbage + Onion	27.00 a	27.91 a	34.68 a	30.48 a	32.97 a	24.49 a	22.58 a	23.17 a	20.37 a	27.10 a
Cabbage + Shallots	28.39 a	21.64 a	26.35 a	21.98 a	25.38 a	22.22 a	20.58 a	18.29 a	23.02 a	23.09 b
Cabbage + Tomato	25.22 a	22.04 a	25.03 a	20.68 a	29.06 a	19.37 a	18.23 a	18.67 a	21.98 a	22.25 b
Grand mean	28.78	24.46	27.17	25.35	28.75	22.68	20.82	20.79	22.75	24.69
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	ns	ns	3.88
S.E	3.6	3.8	5.4	5.7	3.0	4.1	2.4	3.3	2.6	1.74
C.V%	15.32	18.80	24.15	27.27	12.79	22.34	14.09	19.40	14.19	13.21

Means in the same column followed by the same letter are not significantly different ($P>0.05$) according to the LSD test.
ns= F value is not significant at the given probability level

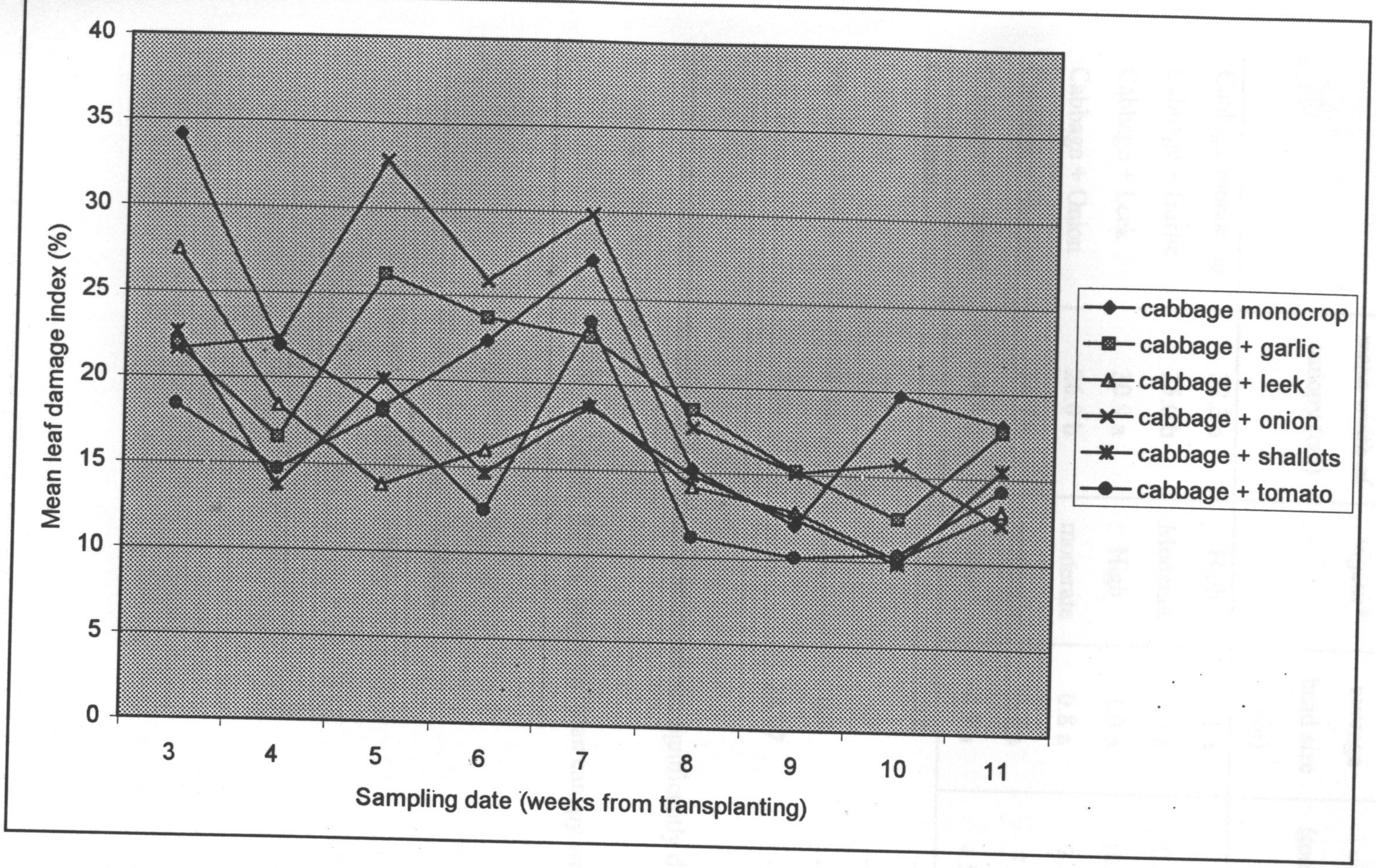

Figure 2: Mean leaf damage index /plot (%)

Table 5: Productivity of cabbage and the intercrop (tons/ha) in the intercropping study at the National Irrigation Research Station in Zambia 1995/96 .

Treatment	Cabbage mean width of canopy (cm)	Cabbage vigour*	Cabbage average head size (Kg)	Intercrop yield (tons/ha)	Intercrop Vigour
Cabbage monocrop	32.3 a	High	1.1 a	-	-
Cabbage + Garlic	25.0 b	Moderate	0.9 a	0.24	low
Cabbage + Leek	30.9 a	High	1.0 a	10.48	high
Cabbage + Onion	26.0 b	moderate	0.8 a	7.12	moderate
Cabbage + Shallots	24.7 b	moderate	0.7 a	7.6	high
Cabbage + Tomato	16.4 c	low	0.5 a	4.56	moderate
Grand mean	25.9		0.8	-	-
LSD 0.05	2.72		ns	-	-
S.E	1.22		0.2	-	-
C.V %	5.74		28.97	-	-

Means in the same column followed by the same letter are not significantly different (P>0.05) according to the LSD test.

* Scale for Vigour Rating, based on mean canopy width of cabbage:

Less than 20 cm = low

20 cm to < 30 cm = moderate

More than 30 cm = high

cabbage intercropped with leek, which had 30.48 tons/ha. Total mean yields for cabbage intercropped with garlic was 28.37 tons/ha, while cabbage intercropped with onion yielded 22.27 tons/ha. Cabbage intercropped with shallots and cabbage intercropped with tomato recorded mean yields of 21.84 tons/ha and 15.55 tons/ha respectively. There were no significant differences (P>0.05) in the mean number of multiheaded plants resulting from pest apical damage between treatments (Table 6). The simple linear Correlation Coefficient (r = + 0.568) between the overall mean number of DBM for the sampling period and the percentage number of multiheaded cabbage plants was not significant (P>0.05). Similarly, the Correlation Coefficient (r = - 0.616) between the overall mean numbers of OCW and the mean percentage number of multiheaded plants was insignificant (P>0.05).

There were no significant differences between treatments (P>0.05), for cabbage marketable yield (Table 7). Cabbage intercropped with leek recorded mean marketable yields of 23.07 tons/ha, followed by cabbage intercropped with garlic (19.09 tons/ha). Cabbage monocrop yielded 17.48 tons/ha, while 14.13 tons/ha was obtained from cabbage intercropped with shallots. Cabbage intercropped with tomato gave yields of 11.76 tons/ha and cabbage intercropped with onion 13.36 tons/ha.

Cabbage monocrop's percentage yield losses associated with pest damage were significantly (P<0.05) higher than for cabbage intercropped with garlic, leek, shallots or tomato. They were however, not significantly different from those for cabbage intercropped with onion (Table 8).

Cabbage intercropped with tomato, followed by cabbage intercropped with leek had the lowest percentage yield losses. The simple linear Correlation Coefficient (r = + 0.759) between the overall mean number of DBM immatures/plant/plot and mean percentage cabbage yield losses due to pest damage insignificant (P>0.05). The simple linear Correlation Coefficient (r = -0.05) between the overall mean number of OCW and the mean percentage cabbage yield losses due to pest damage was also insignificant (P>0.05).

5.6 PARASITOID INCIDENCE (NUMBER OF CACOONS)

Only one species of *Plutella xylostella* (L.), larval parasitoid was found to occur in all the treatments. This was identified as Microgastrinae (Braconidae), the group to which *Apanteles* or *Cotesia* belongs. Pooled ANOVA indicated no significant differences (P>0.05) for the whole (overall) sampling period between treatments (Table 9). There were also insignificant

Table 6: Total mean yield (tons/ha) and percentage multiheaded plants of cabbage in the intercropping study at the National Irrigation Research Station in Zambia 1995/96

Treatment	Total mean yield (tons/ha)	Mean (%) multiheaded cabbage plants
Cabbage monocrop	34.19 a	63.5 a
Cabbage + Garlic	28.37 a	48.4 a
Cabbage + Leek	30.48 a	45.8 a
Cabbage + Onion	22.84 a	56.4 a
Cabbage + Shallots	21.84 a	58.2 a
Cabbage + Tomato	15.55 a	48.7 a
Grand mean	25.55	53.5
LSD 0.05	ns	Ns
S.E	6.93	7.95
C.V %	33.33	18.21

Means in the same column followed by the same letter are not significantly different (P>0.05) according to the LSD test.

Table 7: Total mean marketable yields of cabbage (tons/ha) obtained in the intercropping study at the National Irrigation Research Station in Zambia 1995/96

Treatment	Total mean marketable yield (tons/ha)
Cabbage monocrop	17.48 a
Cabbage + Garlic	19.09 a
Cabbage + Leek	23.07 a
Cabbage + Onion	13.36 a
Cabbage + Shallots	14.13 a
Cabbage + Tomato	11.76 a
Grand mean	16.48
LSD 0.05	Ns
S.E	5.61
C.V %	41.69

Means in the same column followed by the same letter are not significantly different (P>0.05) according to the LSD test.

Table 8: Cabbage mean percentage yield loss/plot (Transformation: Arc-sine) obtained after removal of pest damaged leaves in the intercropping study at the National Irrigation Research Station in Zambia 1995/96

Treatment	Yield loss (%)
Cabbage monocrop	44.79 a
Cabbage + Garlic	34.76 b
Cabbage + Leek	30.72 bc
Cabbage + Onion	40.07 a
Cabbage + Shallots	36.89 b
Cabbage + Tomato	28.68 c
Grand mean	35.98
LSD 0.05	4.99
S.E	3.82
C.V %	7.63

Means in the same column followed by the same letter are not significantly different (P>0.05) according to the LSD test.

Table 9: Mean number of parasitoid cacoons/cabbage plant/ plot recorded in weekly sampling (Transformation: Log (X + 1)) in the intercropping study from October to December, 1995 at the National Irrigation Research Station in Zambia.

Weeks after transplanting (sampling date) Treatment	3	4	5	6	7	8	9	10	11	Overall mean (original data)
	Mean number of parasitoids/cabbage plant									
Cabbage monocrop	0.34 a	0.06 a	0.08 a	0.44 a	0.49 a	0.33 a	0.20 a	0.83 a	1.22 a	3.66 a
Cabbage + Garlic	0.32 a	0.09 a	0.13 a	0.62 a	0.69 a	0.50 a	0.29 a	0.99 a	0.98 a	2.99 a
Cabbage + Leek	0.35 a	0.09 a	0.04 a	0.38 a	0.46 a	0.32 a	0.20 a	0.73 a	1.10 a	2.56 a
Cabbage + Onion	0.20 a	0.12 a	0.14 a	0.63 a	0.72 a	0.41 a	0.32 a	1.09 a	0.99 a	2.86 a
Cabbage + Shallots	0.28 a	0.10 a	0.08 a	0.44 a	0.54 a	0.35 a	0.22 a	0.91 a	0.96 a	2.48 a
Cabbage + Tomato	0.13 a	0.08 a	0.14 a	0.35 a	0.49 a	0.31 a	0.20 a	0.73 a	1.01 a	2.09 a
Grand mean	0.27	0.09	0.10	0.48	0.57	0.37	0.24	0.88	1.04	2.77
$LSD_{0.05}$	ns	ns	ns	Ns	ns	ns	ns	ns	ns	ns
S.E	0.08	0.03	0.05	0.08	0.08	0.12	0.08	0.14	0.18	0.89
C.V%	35.30	31.2	62.26	25.6	15.48	34.72	50.47	19.48	22.1	39.54

Means in the same column followed by the same letter are not significantly different (P>0.05) according to the LSD test.
ns= F value is not significant at the given probability level

differences (P>0.05) between treatments for all the weekly mean number of parasitoid cacoons/cabbage plant/plot (Table 9). The interaction effect of treatment and sampling date was not significant (P>0.05). A graphical illustration indicating seasonal trends showed that the incidence of the parasitoid was low in all treatments in the first few weeks of the sampling. The lowest levels were attained in the 4^{th} and 5^{th} weeks (Figure 3). There was an increase in the mean number of parasitoids in the 10^{th}week in all treatments. For cabbage intercropped with onion, the rise continued into the 11^{th} week. During the same period, a decline was observed in cabbage monocrop, cabbage intercropped with leek and cabbage intercropped with shallots. The simple linear Correlation Coefficient (r = + 0.87) between the overall mean number of parasitoid cacoons and the overall mean number of DBM larvae was significant (P<0.05).

5.7 PARASITISM OF DBM LARVAE

In determining parasitism levels of DBM larvae by *Cotesia plutellae*, pooled ANOVA indicated insignificant differences between treatments (P>0.05), over the 9 weeks sampling period (Table 10). There were no significant differences (P>0.05) between treatments in the overall mean parasitism levels (Table 10). Differences in parasitism between sampling dates were insignificant (P>0.05). The interaction effect of treatment and sampling date was also not significant at the same probability level. There was no clear pattern emerging for the level of DBM parasitism by *Cotesia plutellae*, over the 9 weeks sampling period.

5.8 ECONOMIC POTENTIAL OR PROFITABILITY

Highly varied cash returns were obtained from the various cabbage and intercrop treatments (Table 11). The highest gross margins were obtained from the cabbage + leek combination (K15 127 136 00/ha), followed by cabbage + onion (K 4 085 936 00/ha). The cabbage + shallots combination gave a gross margin of K 3 671 936 00/ha. These combinations had higher gross margins than monocropped cabbage (K 3 369 536 00/ha). Cabbage monocrop gross margin were higher than the cabbage + garlic combination (K 2 767 936 00/ha) and

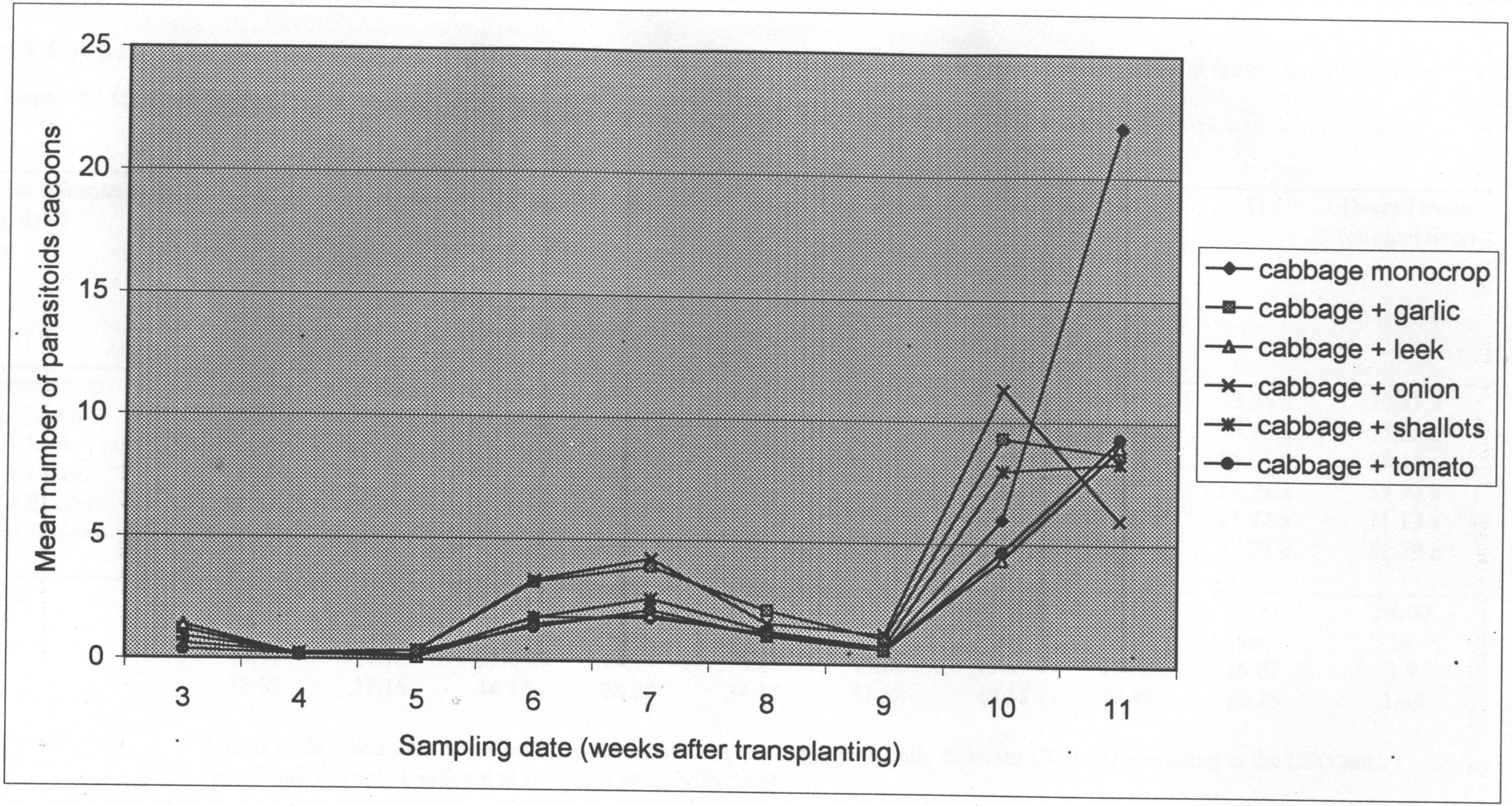

Figure 3: Mean weekly parasitoid cacoons/plant/plot

Table 10: Weekly mean parasitism (%) levels of DBM larvae/plot (Transformation: Arc-sine) recorded in the intercropping study at the National Irrigation Research Station in Zambia from October to December, 1995.

Weeks after transplanting (sampling date) Treatment	3	4	5	6	7	8	9	10	11	Overall mean (original data)
				Mean parasitism level (%) (Based on 3 DBM larvae/plot)						
Cabbage monocrop	65.95 a	70.60 a	52.93 a	65.92 a	48.50 a	48.25 a	48.25 a	52.93 a	35.26 a	50.37 a
Cabbage + Garlic	41.75 a	70.60 a	77.10 a	54.74 a	77.10 a	59.43 a	52.93 a	48.25 a	58.82 a	55.65 a
Cabbage + Leek	35.26 a	88.28 a	65.92 a	48.25 a	77.10 a	54.74 a	52.93 a	48.25 a	88.28 a	57.14 a
Cabbage + Onion	35.26 a	65.92 a	59.43 a	65.92 a	65.92 a	65.92 a	65.92 a	65.92 a	54.74 a	57.93 a
Cabbage + Shallots	35.26 a	48.25 a	41.75 a	35.26 a	52.93 a	52.93 a	59.43 a	52.93 a	43.92 a	51.13 a
Cabbage + Tomato	59.43 a	48.25 a	52.93 a	54.74 a	70.61 a	52.93 a	77.10 a	35.26 a	41.25 a	51.79 a
Grand mean	39.60	65.32	57.34	54.14	65.36	55.7	59.43	50.59	53.71	54.00
$LSD_{0.05}$	ns	ns	ns	Ns	ns	ns	ns	ns	ns	ns
S.E	14.91	14.73	21.04	11.79	18.20	19.09	19.69	15.48	16.07	1.9
C.V%	35.35	27.16	44.18	24.38	34.13	41.98	40.58	37.49	36.25	3.69

Means in the same column followed by the same letter are not significantly different (P>0.05) according to the LSD test.
ns= F value is not significant at the given probability level

Table 11: Gross margins and Net benefits for cabbage and the intercrops based on mean marketable yields (tons/ha) obtained, in the intercropping study at the National Irrigation Research Station, Zambia in 1995/96

Treatment	cabbage (tons)	Intercrop (tons)	Cash sales cabbage K n	Cash sales intercrop K n	Total cash sales K n	Total variable costs K n	Gross margins K n	Net benefit of intercropping K n
Cabbage monocrop	22.93	-	4586 00	-	4 586 000 00	1 216 464 00	3 369 536 00	-
Cabbage + Garlic	19.09	0.24	3818 00	384 00	4 202 000 00	1 434 064 00	2 767 936 00	- 601 600 00
Cabbage + Leek	23.07	10.48	4614 00	11 947 00	16 561 200 00	1 434 064 00	15 127 136 00	+ 11 757 600 00
Cabbage + Onion	13.36	7.12	2672 00	2 848 00	5 520 000 00	1 434 064 00	4 085 936 00	+ 716 400. 00
Cabbage + Shallots	14.13	7.60	2826 00	2 280 00	5 106 000 00	1 434 064 00	3 671 936 00	+ 302 400 00
Cabbage + Tomato	11.76	4.56	2352 00	1 687 00	4 039 200 00	1 729 240 00	309 960 00	- 3 059 576 00

Selling price

Cabbage	K 200/Kg	Onion	K 400/Kg
Garlic	K 1600/Kg	Shallots	K 300/Kg
Leek	K 1140/Kg	Tomato	K 370/Kg

the cabbage + tomato combination (K 309 960 00/ha). Comparisons of the net benefits of cabbage monocropping to the other cropping combinations, indicates that three of the treatments gave positive returns, while the other two recorded negative returns. The cabbage + leek combination gave the highest positive returns (+ K 11 757 600 00 ha) over monocrop cabbage. Returns from the cabbage + onion combination recorded + K 716 400 00/ha) and this was followed by the cabbage + shallots combination which had + K 302 400 00/ha. Negative cash returns were obtained from the cabbage + tomato combination (- K 3 059 576 00/ha) and the cabbage + garlic combination (- K 601 600 00/ha).

6. DISCUSSION

The research has made some important preliminary findings about the Diamondback moth in Zambia. The incidence of the pest was generally low during the study with mean overall DBM immatures of 0.75/plant in cabbage intercropped with tomato, to 1.14/plant in cabbage monocrop. Such DBM densities are relatively lower than those reported by researchers from other regions (Ooi, 1979; Koshihara, 1986; Wan, 1970). Low DBM populations observed in all the cropping cultures evaluated may possibly be attributable to the early on-set of the rainfall and its frequency of occurrence (Figure 4). The period after the 4th week from transplanting appears to be the one most affected by the rains. It could be said that the year had received unusually good rainfall (Appendix 9). Heavy rainfall causes mortality of DBM larvae (Chelliah and Srinivasan, 1986). In turn, low DBM densities tend to lower the precision with which parasitism rates, economic threshold levels and other parameters can be estimated (Srinivasan and Veeresh, 1986).

The study produced somewhat inconsistent results with respect to the effects of the alliums and tomato on DBM populations. During the early growth stage of the cabbage (3rd and 4th weeks from transplanting), garlic, leek and tomato appeared to lower DBM incidence. However, this phenomenon, did not continue thereafter. Subsequent weeks of sampling were characterized by low DBM densities in all the cropping cultures. Cabbage monocrop recorded higher DBM incidence than garlic, leek and tomato in the 3rd and 4th weeks. In this way, previous findings have been confirmed (Burandy and Raros, 1973; Messiean,1992; Talekar et al., 1986). Present results in which leek recorded some suppressing ability on DBM, appear to be at variance with other findings, in which no such indication was observed (Talekar et al., 1986). The rationale on DBM suppression under such situations is that polycultures make it difficult for the pest to find its host. It is likely that the presence of non –host plants in between cabbage rows disrupts

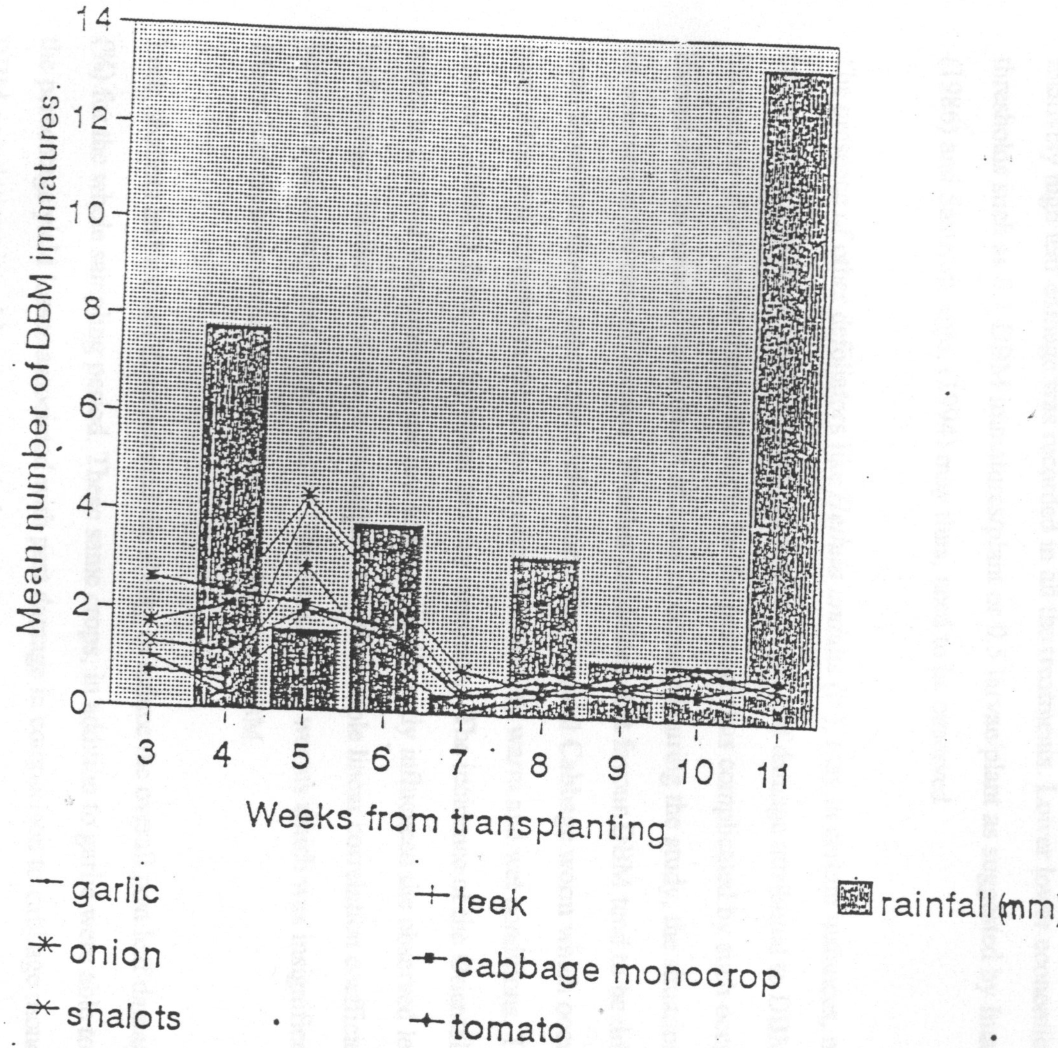

Figure 4: Mean numbers of DBM immatures obtained /plant/plot from weekly sampling of cabbage plants, versus rainfall (mm)

the adult DBM's long-range host seeking mechanisms. There is also a possibility that leek emits some repellent aromatic compounds.

Even if mean DBM incidence per cabbage plant were generally low during the study period, relatively high leaf damage was recorded in all the treatments. Lower lower economic thresholds such as 0.1 DBM immatures/plant or 0.5 larvae/plant as suggested by Iman et al., (1986) and Sastrosiswojo, (1994) may thus, need to be observed.

The presence of other defoliators like *Hellula undu*lis (F.), may in certain instances, make it rather difficult to determine the exact proportion of the leaf damage attributed to DBM. Estimation of economic threshold levels for the pest are thus complicated by such occurrences. Except with an unusual early on-set of rains as occurred during the study, the situation is not so common in the case of Zambia. Weather conditions that favour DBM tend to be different from those that favour most other defoliators. The Oriental Cabbage worm which occurred as part of the pest complex in the study, is often favoured by warm and wet conditions. To the contrary, DBM is favoured by warm and dry conditions. The incidence of the Oriental cabbage worm in the trial was probably too low to have significantly influenced the observed level of leaf damage. Deduction of this is strengthened by the simple linear correlation coefficient between leaf damage and the number of Oriental cabbage worms which was insignificant. Major leaf damage could thus be directly attributed to DBM.

Leek, shallots and tomato demonstrated the ability to reduce the overall pest leaf damage index (%) for the whole sampling period. These same crops, in addition to garlic were able to lower the percentage yield losses associated with pest damage in comparison to cabbage monocrop. DBM populations in cabbage were only kept suppressed by garlic, leek and tomato during the first two weeks after transplanting. However, these crops in the final analysis also had lower percentage yield losses associated with pest damage. Practically, this seems to suggest that control of DBM to reduce yield losses from DBM damage may be of higher necessity during the early growth stage as opposed to later stages. Timing the planting of the intercrop and ensuring minimal disturbance to its growth by external factors such as diseases would be of cardinal importance. In this way, it may be possible to take full advantage of the potential ability of the intercrop to protect the cabbage against DBM. Tomato's full potential in suppressing the DBM in the study is likely to have been masked through destruction of its foliage by Red spider mites and Leaf spot. The understanding is that repellent compounds from the tomato are actually emitted from the plant's leaves (Magallona, 1986). By sucking of the sap in the leaf cells, the mites would cause cell collapse and disrupt release of the volatile compounds that act as repellents. Apart from this, the volatile compounds could to some extent obstruct the volatile compounds due to the fine web coating made on the tomato leaves by the mites. With the later attack of leaf spot, most of the leaf area of the tomato could have become necrotic, further reducing the area available for releasing the repellent compounds. The tomato crop thus needs to be protected under certain conditions that favour development of mites or fungal foliar diseases.

The study has confirmed the presence of *Cotesia plutellae* Kurdjumov in Zambia. In addition, it has re-affirmed the positive numerical responsiveness of the parasitoid to DBM populations as was earlier reported by Alam, (1992). *Cotesia plutellae* Kurdjumov also appeared not to discriminate between cabbage monocrop and the intercropped cabbage. These findings are in agreement with Taleker and Yang, (1993). The observation may suggest that none of the intercrops evaluated would work as antagonists to the parasitoid. It might therefore be possible to combine both the use of parasitoids and intercropping in an integrated management programme for Diamondback moth by farmers.

The mean parasitism rates on *Plutella xylostella* (L.), recorded in the study are in line with those reported in the Philippines (Morallo-Jesus and Sayaboc,1992) and elsewhere. At such high parasitism levels, complete DBM control can be feasible. Even with the high parasitism rates observed for most of the sampling period, the pest still caused some damage to the crop as previously observed (MAWD, 1981). The high parasitism levels recorded should however, be viewed with caution. They may have probably been inflated by both the low densities of DBM in the field and the subsequent low number of reared DBM larvae upon which the parasitism rates were calculated on. Had DBM larvae field densities and their rearing base been much higher during the period, it is expected that lower parasitism rates would have been obtained.

Using the vigour rating criteria for measuring the growth response of cabbage, the cabbage monocrop and the leek + cabbage combination appear to offer the best growing environment. It must however, be realised that leek though grown by some urban market gardeners is not currently widely cultivated by rural gardeners in Zambia. With this, its immediate utilisation by farmers may be limited. The low vigour growth response of cabbage intercropped with tomato suggests incompatibility of the two crops. This could have been due to competition between the cabbage and tomato. The bushy and indeterminate nature of the cultivar used may also have created a restricted light environment for the cabbage. Such conditions are likely to promote more vertical plant growth rather than lateral canopy expansion in a shade sensitive crop like cabbage. Use of determinate cultivars such as Roma, as opposed to indeterminate ones like Money maker might prove useful in avoiding this problem. The alternative could be to use wider inter-row spacing to increase the growing room for the plants.

For the assessment of economic potential or profitability of the various cropping cultures, the leek + cabbage combination, followed by monocrop cabbage gave the highest gross margins. The higher productivity of this combination enabled realisation of higher cash returns. Leek, thus holds some economic potential as a possible cabbage intercrop. The tomato + cabbage combination gave a relatively lower gross margin in the study than other combinations. Lower physical yields obtained from both the tomato itself and the cabbage may have been the major factor that contributed to this. There were also relatively higher variable costs incurred in the management of the tomato crop than for the other intercrops. Tomato's variable costs are however, expected to be lower when conditions are drier. Under dry conditions, the need for labour intensive operations involving pruning, staking and spraying against fungal foliar diseases are at a minimum.

7. CONCLUSION

The study has proved that intercropping of cabbage with garlic, leek shallots and tomato can reduce the percentage yield losses arising from DBM damage. It has also indicated that at the spacing used, leek is able to grow compatibly with the cabbage. Incompatibility was evident when cabbage was intercropped with tomato. Through this work, the existence of the larval parasitoid *Cotesia plutellae* Kurdjumov has been verified. The study confirmed the positive responsiveness of the parasitoid to increasing DBM populations. In addition the existence of relatively high parasitism rates, was confirmed though this did not necessarily result in complete control of the pest. Another important observation made is that non of the intercrops evaluated had an antagonistic effect on the incidence of the parasitoid. It is however, apparent that *Cotesia plutellae* Kurdjumov, can not possibly prevent cabbage yield damage by DBM on its own. Exploration of the possibility of introducing other parasitoid species to compliment it should thus be given consideration.

Due to the preliminary nature of the study, repetition of the experiment may be necessary in order to verify the findings. Modification of the trial by way of increasing the inter-row spacing, especially in tomato should be considered so as to reduce competition between it the cabbage. The alternative would be to use a determinate tomato cultivar instead of an indeterminate one like Money maker. An early start of the study before the on-set of the rains may be required, in order to reduce possible external influences of rainfall on DBM larvae densities and lower the effect of foliar diseases on the tomato.

The study rejects the hypothesis that there are no significant differences in the incidence and yield damage severity of cabbage between the treatments. The study accepts the hypothesis that there are no significant differences in the incidence of parasitoids between treatments.

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9. APPENDICES

Appendix 1 :Weather data from October 1995 to February 1996 and the average mean monthly rainfall (mm) at the same trial period over 14 years from 1980 to 1994 at the National Irrigation Research Station, in Zambia.

Month	Temperature (Centigrade) mean max	Temperature (Centigrade) mean min	Rainfall (mm)	Average mean Monthly Rainfall (mm) over a 14 years period from 1980-1994
September	31.8 *	14.6 *	0 *	0.7
October	32.5 *	17.4 *	50.4 *	32.7
November	31.8 *	18.6 *	86.5 *	66.0
December	28.9 *	18.3 *	92.5 *	150.1
January	29.1 **	18.3 **	216.5 **	206.9
February	28.9 **	18.0 **	156.6 **	175.1

Key for year:

* 1995

** 1996

Source: National Irrigation Research Station Metrological Station.

Appendix 2: Mean number of Diamondback moth larvae and pupae recorded/cabbage plant/plot during weekly sampling in the intercropping study at the National Irrigation Research Station in Zambia from October to December, 1995.

Weeks after transplanting (sampling date) Treatment	3	4	5	6	7	8	9	10	11	Overall mean
				Mean number of DBM immatures						
Cabbage monocrop	2.63	2.40	2.17	1.70	0.30	0.93	0.53	0.50	0.23	1.14
Cabbage + Garlic	1.00	0.47	4.17	2.37	0.43	0.47	0.50	1.10	0.53	1.10
Cabbage + Leek	1.03	0.30	2.03	1.53	0.53	0.70	0.57	0.93	0.87	0.85
Cabbage + Onion	1.73	2.10	4.37	2.60	0.87	0.50	0.97	0.67	0.67	1.37
Cabbage + Shallots	1.33	1.17	2.07	1.80	0.57	0.57	0.70	0.90	0.70	0.91
Cabbage + Tomato	0.73	0.67	2.93	1.00	0.10	0.40	0.67	0.53	0.83	0.75
Grand mean	1.41	1.18	2.96	1.83	0.47	0.6	0.66	0.77	0.63	0.98
$LSD_{0.05}$										ns
S.E										0.20
C.V%										24.21

Means in the same column followed by the same letter are not significantly different ($P>0.05$) according to the LSD test.
ns= F value is not significant at the given probability level

Appendix 3: Comparisons of mean Diamondback moth larvae + pupae between sampling dates at the same treatment level/cabbage plant/plot in the intercropping study at the National Irrigation Research Station in Zambia from October to December, 1995

Weeks after transplanting (Sampling date)	Cabbage monocrop	Cabbage + Garlic	Cabbage + Leek	Cabbage + Onion	Cabbage + Shallots	Cabbage + Tomato
3	2.63	1.00	1.03	1.73	1.33	0.73
4	2.40	0.47	0.30	2.10	1.17	0.67
5	2.17	4.17	2.03	4.37	2.07	2.93
6	1.70	2.37	1.53	2.60	1.80	1.00
7	0.30	0.43	0.50	0.87	0.33	0.10
8	0.93	0.47	0.70	0.50	0.57	0.40
9	0.53	0.50	0.57	0.87	0.70	0.67
10	0.50	1.10	0.93	0.97	0.90	0.53
11	0.23	0.53	0.87	0.67	0.70	0.83
Sampling date mean	1.27	1.23	0.94	1.63	1.06	1.17

Appendix 4 : Mean weekly number of Oriental cabbage worm larvae/cabbage plant/plot recorded in the intercropping study at the National Irrigation Research Station in Zambia from October to December, 1995.

Weeks after transplanting (sampling date) Treatment	3	4	5	6	7	8	9	10	11	Overall mean (original data)
				Mean number of larvae						
Cabbage monocrop	0.2	0.73	0.2	0.17	0.4	0.1	0.2	0.03	0.77	0.27
Cabbage + Garlic	0.2	0.37	0.17	0.37	0.7	0.27	0.4	0.4	0.3	0.32
Cabbage + Leek	0.1	0.37	0	0.6	0.9	0.43	0.7	0.3	0.4	0.3
Cabbage + Onion	0.1	0.5	0.3	0.9	0.83	0.33	0.23	0.53	0.4	0.4
Cabbage + Shallots	0.2	0.53	0.33	0.27	0.6	0.23	0.27	0.63	0.67	0.35
Cabbage + Tomato	0	0.6	0.1	0.27	0.8	0.3	0.27	0.7	0.27	0.33
Grand mean	0.13	0.52	0.18	0.43	0.71	0.28	0.24	0.43	0.47	0.38

Appendix 5 : Weekly mean leaf damage index/plot (%) of cabbage plants recorded in the intercropping study at the National Irrigation Research Station in Zambia from October to December, 1995.

Weeks after transplanting (sampling date) Treatment	3	4	5	6	7	8	9	10	11	Overall mean leaf damage index (%)
				Mean percentage leaf damage index (%)						
Cabbage monocrop	34.13	21.87	18.40	22.40	27.20	15.20	12.00	19.73	18.13	18.99
Cabbage + Garlic	21.87	16.53	26.13	23.73	22.73	18.67	15.20	12.53	17.73	17.53
Cabbage + Leek	27.47	18.40	13.87	16.00	18.83	14.13	12.80	10.13	13.07	13.88
Cabbage + Onion	21.60	22.27	32.80	25.87	29.87	17.60	15.07	15.73	12.27	19.32
Cabbage + Shallots	22.67	13.73	20.00	14.67	18.67	14.80	12.40	9.87	15.47	13.91
Cabbage + Tomato	18.40	14.67	18.13	12.53	23.63	11.20	10.13	10.40	14.27	13.34
Grand mean	24.36	17.91	21.56	19.20	23.49	15.27	12.93	13.07	15.16	16.15

Appendix 6: Mean number of parasitoid cacoons/cabbage plant/ plot recorded in weekly sampling in the intercropping study from October to December, 1995 at the National Irrigation Research Station in Zambia.

Weeks after transplanting (sampling date) Treatment	3	4	5	6	7	8	9	10	11	Overall mean
	Mean number of parasitoids/cabbage plant									
Cabbage monocrop	1.20	0.17	0.20	1.80	1.80	1.27	0.60	6.00	22.00	3.66
Cabbage + Garlic	1.20	0.20	0.37	3.23	3.90	2.17	1.07	9.33	8.67	2.99
Cabbage + Leek	1.40	0.20	0.10	1.53	1.93	1.13	0.60	4.33	9.00	2.56
Cabbage + Onion	0.63	0.27	0.40	3.33	4.23	1.63	1.23	11.33	6.00	2.86
Cabbage + Shallots	0.90	0.27	0.20	1.77	2.60	1.33	0.73	8.00	8.33	2.48
Cabbage + Tomato	0.37	0.20	0.37	1.37	2.13	1.10	0.60	4.67	9.33	2.09
Grand mean	0.95	0.21	0.27	2.17	2.80	1.44	0.81	7.28	10.56	2.77

Appendix 7: Weekly mean parasitism (%) levels of DBM larvae/plot (Transformation: Arc-sine) recorded in the intercropping study at the National Irrigation Research Station in Zambia from October to December, 1995.

Weeks after transplanting (sampling date) Treatment	3	4	5	6	7	8	9	10	11	Overall mean
				Mean parasitism level (%) (Based on 3 DBM larvae/plot)						
Cabbage monocrop	77.78	77.78	55.55	77.78	55.56	55.56	55.56	44.44	33.33	59.26
Cabbage + Garlic	44.44	88.89	88.89	66.67	88.89	66.67	55.55	55.56	55.55	67.90
Cabbage + Leek	33.33	100	77.78	55.56	88.89	66.67	55.55	55.56	100	70.37
Cabbage + Onion	44.44	77.78	66.67	77.78	77.78	77.78	77.78	77.78	66.67	71.61
Cabbage + Shallots	77.78	55.56	44.44	77.78	55.55	55.55	66.67	55.55	44.44	59.26
Cabbage + Tomato	66.67	55.56	55.55	66.67	77.78	55.55	88.89	33.33	55.55	61.73
Grand mean	57.41	75.93	64.81	70.37	74.01	62.96	66.67	53.70	59.26	65.02

Appendix 8: Gross margins and Net benefits for cabbage and the intercrops based on mean marketable yields (Kg/plot) obtained, in the intercropping study at the National Irrigation Research Station, Zambia in 1995/96

Treatment	cabbage (tons)	Intercrop (tons)	Cash sales				Total cash sales		Total variable costs		Gross margins		Net benefit of intercropping
			cabbage		intercrop								
			K	n	K	n	K	n	K	n	K	n	K n
Cabbage monocrop	28.66	.-	5732	00	-		5732	00	1520	58	4211	58	-
Cabbage + Garlic	23.87	0.3	4774	00	480	00	5254	00	1792	58	3461	42	- 601 600 00
Cabbage + Leek	28.77	13.1	5754	00	14 934	00	20 688	00	1792	58	18 895	42	+ 11 757 600 00
Cabbage + Onion	16.70	8.9	3340	00	3560	00	6900	00	1792	58	5113	42	+ 716 400. 00
Cabbage + Shallots	17.67	9.5	3534	00	2850	00	6384	00	1792	58	4591	42	+ 302 400 00
Cabbage + Tomato	14.70	5.7	2940	00	2109	00	5790	00	4661	55	387	45	- 3 059 576 00

Selling price

Cabbage	K 200/Kg	Onion	K 400/Kg
Garlic	K 1600/Kg	Shallots	K 300/Kg
Leek	K 1140/Kg	Tomato	K 370/Kg

Appendix 9: Cabbage mean percentage yield loss/plot obtained after removal of pest damaged leaves in the intercropping study at the National Irrigation Research Station in Zambia 1995/96

Treatment	Yield loss (%)
Cabbage monocrop	49.63
Cabbage + Garlic	32.46
Cabbage + Leek	26.33
Cabbage + Onion	41.57
Cabbage + Shallots	36.46
Cabbage + Tomato	23.08
Grand mean	34.92