VG021
Insecticide resistance and insecticide management for three vegetable pests in South East Queensland

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Queensland Department of Primary Industries

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VG021

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INSECTICIDE RESISTANCE AND INSECTICIDE MANAGEMENT STRATEGIES FOR THREE VEGETABLE PESTS IN SOUTH EAST QUEENSLAND

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QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

Queensland Fruit & Vegetable Growers

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1. Summary

Industry Summary

For diamondback moth the project showed up deficiencies in a prexisting resistance management strategy, (the Three Valley Strategy), which relied on a 'best bet' approach. A modified strategy was then suggested, oriented directly to diamondback moth control. It recommended:-

- removing the ineffective organochlorine and carbamate insecticide groups from the rotation.

- pointed up problem insecticides within the two remaining insecticide groups e.g. prothiotos.

- stressed the need to include alternate insecticide groups with different modes of action within the rotation viz. *Bacillus thuringiensis kurstaki* (B.t.k.).

- supported the benefits of a break in crop production in summer, allowing ecological factors to influence pest numbers.

The modified strategy was promoted, (in association with the QDPI regional extension staff), at two grower evenings, in a newspaper article and as a handout checklist from the Gatton office. Indirect evidence of acceptance has been the consequent massive increase in *B.t.k.* usage in brassica crops (even though *B.t.k.* has been commercially available for over 20 years). Far less incidence of spray failure also occurred, unlike the *annus horribilis* of 1985-86. Other states have instigated similar resistance management strategies (Ridland & Endersby, 1995).

In Queensland, aspects of the insecticide registration status of methomyl and *B.t.k.* have been changed as a result of this project.

For two spotted mite, levels of resistance to four insecticides were shown to be widespread. Monocrotophos resistance appeared to be the most obvious with some strains being homogeneous for high levels of resistance. While dicofol resistance appeared to be quite general, propagate and fenbutatin - oxide resistance was less so. No green peach aphid studies were attempted (see page).

Technical Summary

(i) Diamondback moth

A major finding has been the deficiencies in an existing insecticide resistance management strategy which recommended a continuous rotation of four chemical groups throughout the year, (the Three Valley Strategy).

[One technical limitation in expressing these deficiencies was the unfortunate selection of a susceptable strain, (a laboratory strain form Rothamsted), that was extremely sensitive to the insecticides tested. Consequently resistance ratios, (LD50 of the test strain / LD50 susceptable strain), were quite large.]

Not withstanding, comparing LD50's alone for carbaryl and methomyl, it is clear that high resistance to these chemicals exists. Carbamate insecticide resistance has been detected in Taiwan, Singapore & Japan. (Hiramo 1981).

Endosulfan also had very high LD50 values. Endosulfan is not recommended in SE Asia against DBM but is in India & Nth America. **The carbamate and organochlorine insecticides were removed from the rotation.**

The prothiofos values recorded in the project were in the range quoted by Cheng (1986) in Taiwan for wild strains (1250 - 3120 ppm) but above the susceptables (310 - 420 ppm). Methamidophos values were less than the Florida strains quoted by Leibee and Savage (1990) while pemethrin values quoted by Shelton and Wyman (1990) from Nth. America were generally much higher, expecially in southern USA. **Growers were warned that, within existing insecticide groups, problem chemicals existed.**

At the unsprayed sites in particular, fluctuations in LD50 values were most noticable with permethrin and prothiofos. Georghiou & Taylor (1977) suggested insecticide resistance could be reduced by the immigration of susceptables. Hama (1988) showed that organophosphate resistance could decline drastically with the release of organophosphate selection. It was suspected that reduced LD50's in the Lockyer might be associated with production breaks. **The need to break continuous production became a component of the strategy.**

(ii) Two spotted mite.

Monocrotophos resistance appears to be widespread, with three strains tested being extremely resistant to the chemical. Dicofol resistance also appears to be quite general. Lower levels of resistance to propargite & fenbutatin oxide were detected. **Extension officers in the areas surveyed were warned of the problems with monocrotophos and dicofol.**

2. Recommendations

With the DBM work of this project there was a direct link to QDPI extension via an existing insecticide management strategy. Through promotion of the results of the work during the course of the project, direct influence on this strategy was effected. Usage patterns of insecticides did change.

However in view of the dynamic nature of resistance build-up and the impending entry of new chemistry into the DBM insecticide market, monitoring should be continued.

Good contacts have been made with insecticide companies, extension officers and growers as a result of this work and it is important that this trust continue.

It is recommended that:-

(i) The chemical bioassays continue:-

This is especially necessary with newer insecticides such as diafenthiuron, fipronil, avermectin, azadirachtin, fenoxycarb and pyrrole waiting in the wings of the DBM market.

Not only will bioassays attempt to prolong the market life of the commercial products, they will assist technical publication. The bioassay of field strains of DBM before entry of this new chemistry into marketplace field would allow a more realistic documentation of a 'susceptible' strain.

(ii) The susceptibility to *B.t.k.* be monitored:-

B.t.k. usage allows parasitoids to interact with DBM. It is a cornerstone of resistance management. However excessive dependence on *B.t.k.* puts the whole rotation in jeopardy. None of the other insecticides are as benign to beneficials as the microbial insecticides.

Although other *B.t.k.* formations are also waiting in the wings, preservation of the existing formulations are important.

(iii) There should be an interaction between control of DBM and control of other pest species in the complex:-

This is especially important for Queensland as the suite of brassica pest species is greater. Insecticide registrations often don't span this range of crop and pest species. As QDPI officers can't recommend unregistered insecticides, crop recommendations can be cumborous.

(iv) Encouragement should be given to new chemical means of control that will integrate with existing agronomic practices:-

The recommended production break in mid summer fits into this categorisation. However, the ecological basis for this practice lacks data. The suspicions that resistant strains of DBM are forced from cultivated brassicas to rough forage on wild hosts awaits substantiation.

This project has shown that a resistance management strategy needs ongoing monitoring to assess insecticide efficiency.

With the slower emergence of new chemistry on one hand coupled with resistance to, and a registration review of existing insecticides on the other, few chemicals are available to brassica growers.

To preserve the efficiency of these products an integrated approach should be taken. Ecological consideration can integrate with chemical practice.

3. Technical Report

Introduction

(i) diamondback moth, cabbage moth

***Plutella xylostella* (L.)**

Although a range of parasitoids have been recorded for *P. xylostella* in Queensland, (Yarrow 1970), their control is generally insufficient to regulate *P. xylostella* populations below damaging levels, unlike in the Australian Capital Territory and South Australia (Wilson 1960). In Queensland, *P. xylostella* is merely one of a suite of six caterpillar species regularly attacking brassica crops.

Chemical control has long been an established practice. This was initially with routine sprays of endrin, (Champ 1960) but later with diazinon in the early 1970's. Field resistance to diazinon was noted in 1977, (Hargreaves & Cooper 1978). Pyrethroid usage then spread to brassicas, however Wilcox (1986), Altmann (1988) recorded decreasing sensitivity to permetherin in Lockyer Valley strains. Difficulty with *P. xylostella* control was also recorded in the 1985-86 seasons. (Heisswolf 1992)

To integrate with existing *Helicoverpa armigera* resistance strategies and to gain a better control of *P. xylostella*, the Three Valley strategy was conceived and promoted in August 1988. This strategy recommended the exclusion from use of a specific insecticide group in a systematic monthly rotation throughout the year. (Deuter & Twine 1988, Deuter 1989).

A follow up survey by Heisswolf (1992), showed that although grower acceptance of the Three Valley strategy was initially high, acceptance soon declined as growers found the strategy inflexible and only partially effective.

In view of overseas reports of the capacity of *P. xylostella* to develop insecticide resistance (Sun 1990) and the need to support the Three Valley strategy, monitoring of resistance levels in the Lockyer Valley was undertaken.

Comparison was also made to adjoining brassica production areas in the Granite Belt and the Redlands Metropolitan areas where fewer problems with *P. xylostella* control had been reported.

(ii) Two spotted mite, *Tetranychus urticae* Koch

Green peach aphid, *Myzus persicae* (Sulzer)

Both two spotted mite and green peach aphid are ubiquitous pests of a wide range of vegetable crops. In Queensland, save for the work of Davis & Heather (1962), there is little detail to show the susceptibility of *Tetranychus* strains to commonly used insecticides.

Anecdotal evidence suggests that the control of two spotted mites, especially in heavily sprayed vegetables such as tomatoes, has become increasingly difficult. Consequently, laboratory testing of strains from a range of vegetable growing sites was expected to give some quantification to claims of decreased susceptibility.

Green peach applied is controlled by a range of organochlorine, organophosphate and carbamate insecticides. However, Attia et. al. (1979) found some Lockyer strains of *M. persicae* resistant to some organophosphate and carbamate insecticides. It was hoped that testing of further strains might show how widespread such resistance was in Queensland vegetable growing areas.

Materials and Methods

(i) Diamondback moth (DBM)

Collection of DBM Strains

Broccoli seedlings, either cv. Bonanza, (for summer), or Pacific, (Autumn through until Spring), were grown in soilless mixtures in Speedling® trays, (60 cells/tray), in one of Redlands Research Station's shadehouses. They were watered and fertilised (foliar GF9) until of transplantable size. They were then taken, via covered trays of utility vehicles, to prepared sites at either Gatton Research Station, Lawes, Granite Belt Research Station, Applethorpe or Redlands Research Station, Ormiston. There they were cultivated as per commercial practice, except that no insecticides were applied.

Plants were spaced at 0.3 m intervals within the row, the rows being 0.8m apart.

The plantings were inspected regularly for signs of buildup of *P. xylostella.* Once infestation was established, whole plants were collected and taken to Redlands Research Station. Here the plants were picked over during the succeeding days when all pupae and many forth instar larvae were removed.

Not all plantings yielded *P. xylostella*, especially on the Granite Belt Research Station, when a number of plantings of broccoli were barren of this pest species. Other species, viz cabbage cluster caterpillar. *Crocidolomia pavonana* F. and centre grub, *Hellula hydralis* Guenee, appeared to have displaced *P. xylostella* at these locations.

From farmers' properties, either the infested cut stubs of the brassica residue left in the field, (as at Heisswolf Farm, September 1995), or as many of the whole plants that the grower could give, (as for most samples), were taken and similarly picked over for *P. xylostella.*

In late 1992, a sample of pupae from a laboratory colony of diamonback month was sent to Redlands from the Rothamsted Experimental Station, Harpenden, Hertfordshire, by air freight. This formed the nucleus for the susceptible strain. It had been grown in the laboratory in the United Kingdom for over 20 years.

Rearing

Field collections yielded between 60-200 pupae; this formed the nucleus for the strain to be tested. All tests were completed before the F4 generation. The tests were also run in a set sequence of insecticides.

Pupae were allowed to eclose into 300 x 300 x 300 mm square cages of aluminium framing supporting a fine mesh cotton sleeve. The cages were placed near the laboratory window, maximising the natural light and keeping the moths at ambient temperatures, (18-31°C). Adults were fed a 10% honey solution via 4 x 60 ml glass bottles with dental wicks protruding through their screw top lids.

A potted, (75 mm diameter) unsprayed, broccoli plant at the 4-8 leaf stage of growth was supplied daily for oviposition. Each morning the potted plant was removed to a $0.175m^3$ capacity constant temperature incubator running at 25°C on a 12:12 light cycle. (Whole plant growth was essential as the first intar mines between the leaf surfaces).

After five days the pot was removed, the above ground plant parts harvested and replaced with fresh, unsprayed broccoli leaves in a towelling lined, ventilated plastic lunch box of 300 x 90 x 20 mm dimensions. The lunch boxes were dated, strain marked and stored in the dark, in an ambient to 25°C incubator.

The lunch boxes were examined daily. The towelling and flaccid leaves were removed and replaced with fresh. (Broccoli plants, in 4L plastic pots in a 1:1:4, peat, river sand, red soil mixture, were grown in a glasshouse to serve as a food source).

The larvae pupated in the lunch boxes and were carefully collected with Inox® No.4 jeweller's forceps. Each harvest of pupae was stored in a plastic, 90 mm, petri dish bottom and placed in the emergence cages to begin the cycle anew.

Cross contamination of strains was prevented as far possible, by growing one strain at a time. Initially, storing pupae at 5°C in a refrigerator was tried, but this was not successful, contrary to the success reported by others (Busvine 1980, Altmann 1988). Consequently, on rare occasions two strains ran concurrently, but they were always kept in separate rearing, oviposition and egg eclosion areas.

Insecticide Testing Procedure

Altmann (1988) acted as a harbinger for this study. He used topical application as his technique and to integrate with his results the same method was used. This was essentially the same method as described in Busvine (1980) save that broccoli is the plant host of choice. It was easier to grow than Busvine's turnips.

Third instar *P. xylostella* larvae were removed from their rearing boxes by using a fine paintbrush (000 sable hair) and placed in cells of ten onto a filter paper (Whatmans N°4) on the base of a 90 mm petri dish. (Annumbra). Larvae were anaesthetised by a 2 minute immersion into a 2L glass plastic bucket into which food grade carbon dioxide was allowed to perfuse via a plastic 'T' fitting set into the bucket's base.

After immobilisation, a 0.5 μl droplet of diluted pesticide was applied to the thoracic dorsum in each larvae by using an Arnold hand microapplicator equipped with a 3/10 x 25 luer cannula.

When all larvae for each replicate were treated, a piece of unsprayed broccoli was included for feeding and the glass petri dish lid applied after being marked with the date and treatment. Treatments were replicated 4 times and all dishes were placed in an ambient - 25°C incubator where mortality counts were taken after 24 hours.

Individuals surviving the doses were recorded, individuals were considered dead if no response was made to a needle prod to the body.

All pesticides were made up from technical grade material, obtained from the manufacturer. A stock solution in laboratory grade acetone was made up and kept in volumetric flasks in a refrigerator. Serial dilutions were made from this stock solution. An initial run, over a wide range of concentrations was made. From the lower concentration that gave full mortality, smaller concentration steps were used to gauge mortality more accurately. Serial dilutions were made up in 20 ml glass screw top bottles, agitated by glass beads and a vortex mixer (M19, Chiltern®) for two minutes. Clean pipettes were used for each dilution with laboratory grade acetone. A control batch of insects were treated with acetone only. If the mortality of this group exceeded 10%, the data from this run was rejected.

Data was analysed by probit analysis on the QDPI 'enprobit' programme.

(ii) Two spootted mite, *Tetranychus urticae*
Green peach aphid, *Myzus persicae*

[After the first season's work, it was quite apparent that the inclusion of both the two spotted mite and green peach aphid testing into the resistance programme was going to be logistically very difficult.

Assistance from the project co-leader did not eventuate and facilities at Redlands became strained with *P. xylostella*. Moreover, unsprayed plantings of potatoes and tomatoes at Gatton and Redlands failed to yield colonies of green peach aphid in the first year's plantings.

Consequently it was decided to utilise the insecticide testing facilities of the Biological and Chemical Research Institute, (BCRI), Rydalmere on a fee-for-service basis. The green peach aphid work was abandoned.

Both my departmental supervisor and HRDC reviewers Davenport and Gregory were advised of this decision (Appendix1). To compensate for this omission, approximately one third of the funds originally allocated 1990-91, 1991-92 were deliberately left unspent and allowed to lapse back to the funding body.]

Field Collection

Twelve strains of *T. urticae* were collected from insecticide treated vegetable crops in the Granite Belt, Redlands & Lockyer districts. Infested leaves were firmly packed into 300 x 150mm kraft paper bags, sealed and placed in a 250 x 170 x 170mm polystyrene cooler box. A paper towelling wrapped freezer block had already been placed into the polystyrene box. After sealing, the box was dispatched to BCRI by overnight courier.

Testing Method

Dr G. Herron's method at BCRI, was as described by Edge & James(1982). For each dose 25 individuals plus a water only treated control were sprayed using a Potter spray tower. Each concentration of insecticide sprayed was replicated once to give approximately 150 individuals treated per dose. Log dose-probability assays were analysed by probit analysis (Finney 1971) and the diagnostic doses are presented as per cent mortality at the discriminating concentration and 5x or 10x the discriminating concentration. All results were corrected for control mortality (Abbott 1925).

One strain only was tested for the full log dosage-probability regression method. All others were tested by discriminating dose. Four insecticides were tested: dicofol (Kelthane ® - an organochlorine); monocrotophos (Azrodrin ®, Nuvacron ® - an organophosphate); fenbutatin - oxide (Torque® - an organotin);. propargite (Omite® - a cyclo compound).

Results

(i) Diamondback moth

For ease of comparison, the results of the earlier work by Altmann (1988) are listed in table 1.

Pyrethroid Insecticides

(1) Permethrin

The results of the topical application for permethrin are summarised in tables 2, 3, 4 & figures 1 & 2.

A comparison of table 1 with table 2, shows increasing LD50 values for Lockyer strains collected from 1985 - 1987, rising to a high of 658 ppm.

Table 2 shows the results of the current study. It shows a subsequent drop in values in 1988 compared with Altman's study. This is followed by a high in 1989, with some strains, (e.g. Gatton Research Station), being significantly higher than some earlier values, (i.e. their confidence intervals don't overlap).

For 1990-91, values are again significantly lower, especially on the unsprayed collections taken at Gatton Research Station.

Comparison of the resistance ratios in figures 1 & 2 show that the unsprayed plantings at Gatton Research Station mirror similar trends in commercial plantings from the Lockyer district. Thus the unsprayed site, at this location, appears to act as a reasonable trap for resistant strain of immigrant *P. xylostella* adults. This is not surprising, for commercial brassica growing consistently occurs in close proximity to the Research Station.

The reason for the fall in LD50 values after the high in 1989 is unknown. According to extension officers (Heisswolf, Deuter 1992, personal communication), a break in production over the summer period was most marked over 1990 & 1991. This break was chiefly for agronomic reasons, (water supply and lack of good varieties of broccoli for summer), however the entomological advantages may also have been a small consideration.

Resistant strains appear to have been diluted with susceptibles by the 1990 season. This dilution is marked in both the commercial as well as the unsprayed sites sampled.

In addition, deficiencies in the older strategy of chemical rotation (the 3 Valley Strategy - mentioned earlier), were becoming apparent and growers were specifically advised against using specific chemicals and also chemical groups.

The insect bacterial formulations of *Bacillus thuringiensis kurstaki*, Dipel®, (Abbot) Thuricide®, (Sandoz), Biobit® (Nufarm) were also strongly recommended to take up the slack from the omission of less effective insecticide groups. It was known that the current explosion in usage of *B. thuringiensis* in brassicas in Queensland started around this time.

Table 3 shows the results at the Redlands site and table 4, the Applethorpe site. Perhaps less obviously, these sites also show a downward trend, although overall, their values are less than these recorded for the Lockyer. (figures 1 & 2).

The brassica production, at both the Redlands and Applethorpe districts, is more fragmented. At Redlands, although ancestraly a brassica growing area, the farms are now not contiguous and brassicas are cultivated opportunistically, dependent on market forces. In the Granite Belt, growing time is more consistent but the discrete growing areas are widely separated, generally by rocky outcrops surrounded by scrub. It is suggested that this spatial and temporal separation may act as a barrier to the immigration of resistant strains into cropping situations.

In terms of grower usage, permethrin, (Ambush®) is now not a widely used insecticide, its use peaking in the late 70's & early 80's. Fenvalerate, initially as Sumicidin®, but later as Hallmark®, and Deltametherin, as Decis®, supplanted permetherin usage around the mid 1980's.

(2). Fenvalerate

The results of the dosing with fenvalerate are shown in table 5. Although fewer in number of samples than permetherin, regional differences are less apparent than with permethrin. Some variations, (some significant), do occur between collection sites but most LD50 values are similar.

This may reflect a wide spread selection for fenvalerate resistance. Hallmark® is a widely used pyrethroid in all three locations.

(3) Deltamethrin

Deltametherin dosing results are shown in table 6. Again, both Redlands & Lockyer values appear to be similar, with few significant differences. By contract Granite Belt values are significantly lower, which is hard to rationalise as deltamethrin, as Decis®, is widely used in all three locations.

(4) Cyfluthrin

Cyfluthrin, as Bulldock®, (beta cyfluthrin), became commercially available after this study finished. Consequently fewer strains of *P. xylostella* were tested to this product. LD50 values were lower than for other pytheroids with little within- location differences as shown in table 7.

(5) Lambda cyhalothrin

This insecticide also became commercially available only towards the end of the study. Altmann (1988) tested the experimental material and comparison of table 1 and table 8 shows higher LD50 values than Altmann's earlier results, from most locations tested.

Organophosphate Insecticides.

(1) Prothiophos

Prothiophos results are shown in table 9 and figures 3 & 4. The Lockyer district shows a higher incidence of resistance than the Redlands or Granite Belt, even on the unsprayed plantings (see figures 3 & 4).

At the unsprayed plantings at Gatton Research Station however, there is a trend downwards from a 1989 high with 1991 values being significantly less than August 1989.

Prothiofos, as Tokuthion®, is a widely used insecticide in all three areas. It is one of the few insecticides capable of controlling the whole spectrum of the six species of brassica pest lepidoptera Not surprisingly, considering the LD 50 values shown, Tokuthion® was a common chemical used in reported on-farm failures.

(2) Methamidophos

Methamidophos results are shown as table 10 and figures 5 and 6. Again, a higher level of resistance occurred in the Lockyer than in Redlands or Granite Belt districts, although these last two areas vary. Fisher and Cross in Redlands, Poole and Harslett in the Granite Belt have elevated values.

At all locations, the unsprayed sites gave similar values to their surrounding districts.

Methamidophos, as Nitofol®, Prefect® or Monitor®, has been widely used in some brassica crops, where its aphicidal action is also appreciated However it is not registered for use in broccoli (Beavis and Simpson 1992). This may have restricted its usage, as broccoli forms a substantial propotion of the brassica production in the Lockyer and Granite Belt areas.

(3) Methidathion

Methidathion dosing results are shown in table 11 and figures 7 and 8. Except for an occasional low value, on-farm collections show little difference between the three districts. Higher values occured on the unsprayed sites at Gatton than elsewhere although later figures for Redlands were trending upwards.

Compard to prothiofos, both methidathion and methamidophos have much lower resistance ratios (cf. figures 7 and 8 to figures 3-6).

In contrast to other chemicals tested, the slopes of the probit lines for methidathion are more uniformly steeper. This may be indicative of more homogeneous populations for methidathion susceptability.

Although methidathion, as Supracide®, is registered for most commercial brassica crops, it does not find wide commercial usage. In view of the higher resistance values for other insecticides, for example prothiofos, this would appear to be a serious omission.

(4) Mevinphos

Mevinphos, (Phosdrin®), results are shown in Table 12. Again all three districts appear to show a similar range of LD 50 values.

At the one site, however, a considerable variation occurred with time. Values at Gatton Research Station ranged from 434 ppm in July 91 to 39 ppm in September of the same year. This may reflect immigration of susceptibles from wild hosts in brassicaceous weeds which are abundant throughout the winter in the Lockyer Valley.

The slopes for mevinphos, like methidathion, are also substantially steeper than the other insecticides tested.

Phosdrin® is not widely used as a routine brassica crop spray although it is registered for such use (Beavis and Simpson 1992). This is possibly because of its acute mammalian toxicity (LD 50 3mg/kg, white albino rats - Thompson 1994) and more particularly, its high cost.

However it does find use as a clean-up spray for established populations, especially closer to harvest, where its withholding period of 2 days makes it extremely useful.

(5) Diazinon

Diazinon testing results are shown in table 13. The extremely high values obtained shows an extremely high resistance to this chemical for all sites. Because of the universality of high values for resistance, only a limited number of samples were taken.

In the field, diazinon usage, (chiefly as Gesapon®), rapidly supplanted the earlier use of endrin. Diazinon usage continued from 1970 until 1977 when field resistance to diazinon was detected in the Lockyer Valley and the pyrethroids started to become commercially available.

Chlorinated hydrocarbon insecticides

(1) Endosulfan

The endosulfan dosing results are shown in table 14. All locations show extremely high LD 50 values, consequently limited samples were taken for this chemical.

Endosulfan, (Thiodan®, Endosan®), found wide usage in brassica vegetables, often in association with methomyl.

On the basis of its high LD 50 values, its utility as a control must be questioned.

Carbamate insecticides

(1) Carbaryl and methomyl

Results for both carbaryl and methomyl are shown in table 15. All locations show high resistance values for these chemical groups.

Both carbaryl, (e.g Bugmaster®) and methomyl (e.g. Nudrin®, Marlin®, Lannate®) are used in brassicas where they have registration for a range of pest lepidoptera. They are generally used at times of lower population numbers.

Their usage must be questioned in view of the very large LD 50 values recorded.

For other carbamate insecticides, only thiodicarb, (Larvin®), was being considered as a commercial brassica insecticide at the time of this study.

Field tests at Redlands with the chemical showed that it needed a large concentration to give any measure of control, (table 16), and that its control was not as good as a prothiofos standard.

Moreover, Rhône-Poulenc trials at Redlands had shown poor performance of thiodicarb against *P xylostella* (McGregor D., 1992, personal communication).

All things considered, diamondback moth appeared to be resistant to many of the carbamate insecticides.

(ii) Two spotted mites.

The only strain analysed by probit regression was the Forest Hill strain, (Table 7) all others were bioassayed by discriminating dose. These results for fenbutatin oxide, propargite, dicofol and monocrotophos are show in tables 18-21.

For fenbutatin oxide, the discriminating dose was adjusted part way through the assays. it was adjusted from 0.003% a.i. to 0.002% a.i. after receipt of a new batch of insecticide. For all strains from 1991, either a x5 or a x10 discriminating dose was used, rather than both.

Discussion

(i) Diamondback moth

Studies of insect resistance often express results in terms of a Resistance Ratio (RR). This is calculated by dividing the LD50 of the strain in question by the LD50 of a known susceptible strain. This suceptable is often a laboratory breed strain.

With this study the English (Rothamshed) strain was used. However this strain had been maintained continuously in the laboratory for over twenty years, with little insecticide challenge. As a consequence, the results showed that it was extremely susceptible to the insecticides tested. For example, its value for permethrin was 1.2ppm but laboratory strains in Victoria were 5ppm, (Endersby & Ridland 1995), in Japan 3.3ppm (Kobayashi et. al. 1990), in New York 33ppm (Shelton & Wyman 1992). Consquently for this work, expressions of resistance ratio were expected to be large, possibly unnaturally so.

Some authors have suggested instead that susceptible standard strains should be taken from the field, prior to exposure to the insecticides to be tested (Roush & Tabashnik 1990), for even with laboratory strains considerable differences occur (Sarwicki 1987).

Field collection was not possible in this study as all areas had a history of usage of the particular insecticides. Consequently the resistance ratios in this study appear quite large for some of the insecticides quoted.

The high levels of resistance to the carbamate insecticides registered for *P. xylostella* control is quite apparent. This, coupled with information on the apparent insensitivity of thiodicarb to *P. xylostella*, another carbamate insecticide, suggested entrenched carbamate resistance. Carbamate resistance has been recorded overseas (Liu et. al. 1982).

Consequently, an existing registration of methomyl for *P. xylostella* contol (Beavis 1989), made by the Queensland Agricultural Requirements Board was successfully challenged, (Appendix 2), (Beavis & Simpson 1992). Endosulfan also appeared to be of limited efficiency. So the organochlorine & carbamate insecticide groups were removed from the Three Valley strategy.

Diazinon, in the organophosphate insecticide group was also quite ineffective. In additiion, strains from the Lockyer Valley in particular, showed high levels of prothiofos resistance. Incipient resistance to methamidophos appeared in the Lockyer. Methidathion and mevinphos appeared less problematic.

In the pyrethroids, resistance appeared to be coming to fenvalerate and deltamethrin. However values for permethrin fluctuated. Drops in resistance levels appeared to be associated with production breaks in the continuous cropping of brassicas. Such production breaks have been recommended as a management strategy by Sun (1989, 1992). This drop in resistance values was exploited in promotion of the modified strategy on grower evenings on 12 October 1992 (Gatton) and 29 October 1992 (Granite Belt), when results were tabled.

The modified strategy included a summer production break; a rotation of insecticide groups exclusive of the chlorinated hydrocarbons & carbamates; a wariness for prothiofos and the use of mevinphos especially as a clean up spray. In addition, *Bacillus thuringiensis kurstaki* (*B.t.k*) usage was promoted (Heisswolf 1993). Additional registrations to promote acceptance of *B.t.k.* were sought via the Queensland Agricultural Requirements Board, (Appendix 2).

Registrations for a per hectare usage rate and a registration for control of an associated pest *Crocidolomia pavonana* were successful.

Because of the very low slope values for the regression line for dosage and mortality, it was not possible to select a discriminating dose to separate susceptible from resistant strains of *P. sylostella*. Classically, with discrete populations with steeper slope values, a dosage can be calculated which discriminates. This dosage allows very few susceptibles to survive while it has little effect on the resistant phenotypes, (Roush & Tabashnik 1990).

When the results of testing insecticides on populations from unsprayed sites are examined considerable variation is apparent. It is suspected that immigration of susceptibles, probably from populations from wild hosts is occurring. This influx dilutes the resistance values on the cultivated crop.

As a rough guide, a 'rule of thumb', the following values would appear to arbitrarily discriminate between brassica growers that suffered control failure and those that did not.

Permethrin, 100ppm; deltamethrin, 100ppm; prothiophos, 750ppm; methamidophos, 1000 ppm; methidathion, 750 ppm; mevinphos, 500ppm.

(ii) Two spotted mites

Resistance to all four insecticides was detected in the Forest Hill strain and was at a very high level for Nuvacron®.

All other strains showed degrees of resistance to Nuvacron®, with no strain having >90% mortality at the discriminating dose. Eleven of the twelve strains had <50% mortalities at the discriminating dose, with three strains having <10% mortalities. This indicates a severe lack of susceptable individuals and is likely to indicate high levels of resistance. In strains Ormiston, April '91; Wellington Point, September '91 and Gatton, June '90 a x10 increase in dose gave no corresponding increase in response, possibly indicating highly resistant homogeneous strains.

Only three strains of the twelve tested to Kelthane® had >90% mortalities at the discriminating dose. Low level dicofol resistance is apparently not common. Eight strains had <50% mortalities. In all instances an increase in dose gave an increase in % mortality indicating a degree of heterogeneity.

Omite® resistance was marginally less common than Torque® resistance as it was only detected in eight of the twelve strains. Four strains had discriminating dose mortalities >90%, indicating low level resistance. Two strains had <50% mortality at the discriminating dose.

Although suspect resistance was detected in all strains tested to Torque®, six strains had discriminating mortalities >90%. This indicates very low level resistance. Two strains, (Ormiston, Jan '91 and Wellington Pt., Sep '91) had discriminating dose mortalities <50%, which may indicate higher levels of Torque resistance.

Table 1:
Permethrin

Altmann (1988)

Collection site		n.	LD50 (ppm)	slope ± s.e.	RR
Wilcox	1985		39	3.653	
Laboratory Strain	1987	180	247 (170-374)	1.315 ± 0.226	1
Field Strain 1	1987	180	353 (259-510)	1.698 ± 0.276	1.4
Field Strain 2	1987	180	658 (445-1221)	1.415 ± 0.246	2.7
Lamba cyhalothrin					
Laboratory Strain	1987	180	20 (12-30)	1.209 ± 0.262	1
Field Strain 1	1987	180	116 (58-1193)	0.929 ± 0.294	5.8
Field Strain 2	1987	180	129 (68-747)	1.056 ± 0.287	6.5

Table 2: Permethrin

Lockyer District

Collection site		n.	LD50 (ppm)	slope ± s.e.
Gatton Research Station	Sept 1988	230	130 (84-219)	0.909 ± 0.140
Gatton Research Station	April 1989	240	728 (350-1241)	0.821 ± 0.111
Gatton Research Station	Aug 1989	268	733 (421-1276)	0.834 ± 0.082
Gatton Research Station	June 1990	240	84 (58-119)	1.484 ± 0.181
Gatton Research Station	March 1991	178	105 (55-187)	0.846 ± 0.125
Gatton Research Station	July 1991	180	103 (46-205)	0.722 ± 0.099
Gatton Research Station	Sept 1991	240	68 (22-166)	1.025 ± 0.189
Gatton Research Station	Jan 1992	240	135 (90-201)	1.179 ± 0.138
Goos Farm	Nov 1988	210	269 (146-491)	0.739 ± 0.104
Storey Farm	Feb 1989	240	390 (158-731)	0.670 ± 0.111
Brittingham Farm	Nov 1989	210	367 (197-662)	0.780 ± 0.096
Diete Farm	Jan 1991	240	34 (16-77)	0.532 ± 0.066
Kanofski Farm	March 1991	210	143 (39-374)	0.906 ± 0.167
Gatton Cooperative	March 1991	360	163 (83-279)	1.253 ± 0.201
Jull Farm	April 1991	180	58 (17-131)	0.673 ± 0.116
Kamholtz Farm	July 1991	180	185 (115-302)	1.146 ± 0.156
Heisswolf Farm	Sept 1991	240	106 (57-182)	0.963 ± 0.117

Table 3: Permethrin

Redlands District

Collection site		n.	LD50 (ppm)	slope ± s.e.
Redlands Research Station	April 1989	240	18 (1-56)	0.787 ± 0.192
Redlands Research Station	Oct 1989	270	21 (9-44)	0.553 ± 0.064
Redlands Research Station	July 1990	180	1 (0.1-3)	0.569 ± 0.116
Redlands Research Station	Oct 1990	210	1 (0.3-2)	0.838 ± 0.188
Redlands Research Station	Feb 1991	180	9 (3-18)	0.725 ± 0.109

Redlands Research Station	Nov 1991	240	51 (22-101)	0.741 ± 0.099
Nemesi Farm	May 1989	179	72 (42-116)	0.956 ± 0.109
Wilson Farm	Jan 1991	210	59 (28-139)	0.548 ± 0.068
Moore Farm	March 1991	177	19 (9-38)	0.894 ± 0.131
Pongrazio Farm	Dec 1991	237	72 (18-196)	0.904 ± 0.179
Fischer Farm	Feb 1992	240	262 (148-454)	0.682 ± 0.070
Freeman Farm	June 1992	248	152 (81-275)	0.727 ± 0.083
Cross Farm	June 1992	247	78 (38-144)	0.743 ± 0.089

Table 4: Permethrin
Granite Belt District

Collection site		n.	LD50 (ppm)	slope ± s.e.
Granite Belt Research Station	Dec 1990	208	22 (11-40)	0.824 ± 0.101
Archejacano Farm	Nov 1988	208	66 (48-86)	1.750 ± 0.214
Poole Farm	Feb 1990	238	37 (20-60)	0.874 ± 0.122
Sweete Farm	Nov 1990	206	1 (0-5)	0.627 ± 0.175
Harslett Farm	Jan 1992	245	36 (18-66)	0.819 ± 0.103
Dixon Farm	April 1992	245	72 (44-115)	1.175 ± 0.144
English Laboratory strain	June 1993	282	1.2 (0.7-1.9)	0.958 ± 0.094

Table 5: Fenvalerate

Collection site		n	LD 50 (ppm)	slope ± s.e.
Lockyer District				
Gatton Research Station	March 1991	191	326 (185-543)	1.004 ± 0.149
Gatton Research Station	July 1991	185	306 (172-512)	0.956 ± 0.125
Gatton Research Station	Sept 1991	241	67 (30-122)	0.838 ± 0.116
Diete Farm	Jan 1991	213	230 (103-547)	0.560 ± 0.070
Jull Farm	April 1991	176	134 (74-216)	1.309 ± 0.226
Kamholtz Farm	July 1991	176	499 (286-887)	1.025 ± 0.126
Heisswolf Farm	Sept 1991	227	252 (119-492)	0.719 ± 0.097
Redlands District				
Redlands Research Station	March 1991	174	93 (38-182)	0.731 ± 0.124
Redlands Research Station	Nov 1991	237	214 (109-389)	0.733 ± 0.086
Wilson Farm	Jan 1991	209	188 (95-367)	0.789 ± 0.105
Pongrazio Farm	Dec 1991	235	245 (138-412)	0.956 ± 0.110
Fischer Farm	Feb 1992	238	386 (107-418)	0.698 ± 0.085
Freeman Farm	June 1992	245	223 (108-418)	0.699 ± 0.085
Cross Farm	June 1992	244	143 (74-255)	0.839 ± 0.103
Granite Belt District				
Granite Belt Research Station	Dec 1990	177	121 (57-253)	0.698 ± 0.089
Harslett Farm	Jan 1992	236	194 (117-309)	0.924 ± 0.111
Dixon Farm	April 1992	241	47 (22-83)	0.992 ± 0.35
English Strain	June 1993	282	0.05(0.03-0.08)	0.819 ± 0.086

Table 6: Deltamethrin

Lockyer District				
Collection site		**n**	**LD 50 (ppm)**	**slope ± s.e.**
Gatton Research Station	March 1991	179	173 (95-283)	1.158 ± 0.161
Gatton Research Station	July 1991	185	125 (62-245)	0.738 ± 0.092
Gatton Research Station	Sept 1991	235	50 (21-101)	0.623 ± 0.085
Diete Farm	Jan 1991	179	125 (59-232)	0.830 ± 0.110
Jull Farm	April 1991	173	359 (205-687)	1.039 ± 0.128
Kamholtz Farm	July 1991	176	535 (233-1239)	0.691 ± 0.110
Heisswolf Farm	Sept 1991	184	205 (116-352)	0.924 ± 0.107
Redlands District				
Redlands Research Station	Feb 1991	203	29 (13-58)	0.670 ± 0.081
Wilson Farm	Jan 1991	209	101 (61-162)	1.064 ± 0.130
Pongrazio Farm	Dec 1991	239	161 (78-305)	0.753 ± 0.102
Fischer Farm	Feb 1992	248	92 (59-145)	1.079 ± 0.111
Griffin Farm	June 1992	246	180 (128-267)	1.176 ± 0.132
Cross Farm	June 1992	236	288 (148-570)	0.634 ± 0.077
Granite Belt District				
Granite Belt Research Station	Dec 1990	178	2 (0.9-5)	0.766 ± 0.129
Harslett Farm	Jan 1992	269	17 (8-30)	0.996 ± 0.146
Dixon Farm	Apr 1992	243	35 (16-65)	0.785 ± 0.100
English Laboratory Strain	June 1993	397	0.03(0.02-0.04)	1.135 ± 0.107

Table 7: Cyfluthrin

Collection site		**n**	**LD 50 (ppm)**	**slope ± s.e.**
Lockyer District				
Gatton Research Station	July 1991	213	7 (3-16)	0.666 ± 0.095
Gatton Research Station	Sept 1991	238	50 (26-87)	0.981 ± 0.126
Heisswolf Farm	Sept 1991	237	27 (9-58)	0.926 ± 0.166
Redlands District				
Redlands Research Station	Nov 1991	247	45 (23-78)	0.963 ± 0.124
Pongrazio Farm	Dec 1991	234	88 (54-134)	1.063 ± 0.140
Fischer Farm	Feb 1992	238	68 (43-105)	1.209 ± 0.129
Freeman Farm	June 1992	233	27 (17-39)	1.387 ± 0.171
Granite Belt District				
Harslett Farm	Jan 1992	196	11 (5-20)	1.023 ± 0.149
Dixon Farm	Apr 1992	242	19 (9-33)	0.872 ± 0.110
English Laboratory Strain	June 1993	241	0.02 (0.005-0.048)	0.658 ± 0.109

Table 8: Lambda cyhalothrin

Collection site		**n**	**LD 50 (ppm)**	**slope ± s.e.**
Lockyer District				
Heisswolf Farm	Sep 1991	278	261 (150-470)	0.772 ± 0.078
Redlands District				
Pongrazio Farm	Dec 1991	235	355 (217-584)	1.014 ± 0.107
Fischer Farm	Feb 1992	243	221 (141-338)	1.013 ± 0.121
Freeman Farm	June 1992	231	78 (38-138)	0.867 ± 0.121
Granite Belt District				
Harslett Farm	Jan 1992	245	101 (62-165)	0.985 ± 0.103
Dixon Farm	Apr 1992	243	132 (82-211)	1.056 ± 0.110
English Laboratory Strain	Jan 1993	270	0.1 (0.07 ± 0.17)	1.000 ± 0.096

Table 9: Prothiofos

Collection site		**n**	**LD 50 (ppm)**	**slope ± s.e.**
Lockyer District				
Gatton Research Station	Sept 1988	330	6944 (4833-12651)	1.664 ± 0.326
Gatton Research Station	Apr 1989	209	2179 (1046-3497)	1.114 ± 0.185
Gatton Research Station	Aug 1989	209	9793 (5936-16442)	0.940 ± 0.116
Gatton Research Station	Jan 1990	240	3983 (2445-6724)	0.865 ± 0.099
Gatton Research Station	Mar 1991	176	1699 (1164-2391)	2.031 ± 0.359
Gatton Research Station	July 1991	176	1307 (709-2419)	0.909 ± 0.110
Goos Farm	Nov 1988	270	5210 (3596-7825)	1.100 ± 0.117
Marschke Farm	Nov 1988	240	2346 (1661-3389)	1.228 ± 0.145
Storey Farm	Feb 1989	180	3935 (2060-6581)	1.009 ± 0.171
Brittingham Farm	Nov 1989	438	520 (274-930)	0.546 ± 0.049
Diete Farm	Jan 1991	233	1177 (672-1916)	1.067 ± 0.156
Kanofski Farm	Mar 1991	173	2999 (1724-5441)	0.909 ± 0.124
Jull Farm	Apr 1991	177	2362 (1180-4630)	0.857 ± 0.127
Gatton Cooperative	Apr 1991	179	1608 (574-4559)	0.489 ± 0.085
Kamholtz Farm	July 1991	181	956 (463-1840)	0.908 ± 0.129
Heisswolf Farm	Sept 1991	237	2290 (1391-3810)	0.937 ± 0.101

Redlands District				
Redlands Research Station	Apr 1989	332	75 (29-164)	0.455 ± 0.055
Redlands Research Station	Oct 1989	267	433 (237-787)	0.723 ± 0.073
Redlands Research Station	July 1990	237	225 (128-386)	0.887 ± 0.103
Redlands Research Station	Oct 1990	215	342 (203-568)	1.014 ± 0.110
Redlands Research Station	Mar 1991	173	740 (371-1359)	1.061 ± 0.158
Redlands Research Station	Sept 1991	207	527 (233-984)	0.868 ± 0.124
Redlands Research Station	Nov 1991	253	595 (294-1127)	0.691 ± 0.092
Nemesi Farm	May 1989	299	467 (211-890)	0.585 ± 0.070
Wilson Farm	Jan 1991	205	1571 (883-2825)	1.084 ± 0.140
Moore Farm	Mar 1991	180	830 (359-1822)	0.647 ± 0.093
Pongrazio Farm	Dec 1991	239	179 (95-307)	1.044 ± 0.139
Fischer Farm	Feb 1992	239	656 (346-1138)	0.960 ± 0.132
Freeman Farm	June 1992	241	501 (152-1293)	0.846 ± 0.158
Cross Farm	July 1992	251	898 (525-1551)	0.870 ± 0.087
Granite Belt District				
Granite Belt Research Station	Dec 1990	179	116 (68-183)	1.501 ± 0.215
Archejacano Farm	Nov 1988	330	1025 (723-1455)	1.244 ± 0.155
Poole Farm	Feb 1990	210	181 (97-305)	0.995 ± 0.134
Sweete Farm	Nov 2990	210	677 (405 - 1082)	1.162 ± 0.155
Harslett Farm	Jan 1992	180	2486 (1351-4851)	0.865 ± 0.111
Dixon Farm	Apr 1992	288	756 (500-1115)	1.141 ± 0.113
English Laboratory Strain	June 1993	302	11 (7-14)	1.423 ± 0.142

Table 10: Methamidophos

Collection site		n	LD 50 (ppm)	slope ± s.e.
Lockyer District				
Gatton Research Station	Aug 1989	208	3032 (1562-5955)	0.808 ± 0.112
Gatton Research Station	June 1990	239	1681 (506-4413)	0.862 ± 0.164
Gatton Research Station	May 1991	176	1522 (875-2738)	0.922 ± 0.170
Gatton Research Station	July 1991	175	3804 (2519-5711)	1.422 ± 0.193
Gatton Research Station	Sep 1991	234	3693 (2269-6184)	1.012 ± 0.113

Brittingham Farm	Nov 1989	270	4171 (2703-6331)	1.198 ± 0.198
Diete Farm	Jan 1991	177	117 (46-270)	0.662 ± 0.111
Kanofski Farm	Mar 1991	175	1743 (1028-2984)	1.151 ± 0.143
Kamholtz Farm	July 1991	178	2209 (1249-4011)	0.973 ± 0.120
Heisswolf Farm	Sept 1991	233	1642 (714-4190)	0.825 ± 0.127
Redlands District				
Redlands Research Station	April 1989	232	87 (86-202)	0.487 ± 0.071
Redlands Research Station	Oct 1989	236	127 (23-400)	0.564 ± 0.108
Redlands Research Station	July 1990	181	612 (254-1161)	0.874 ± 0.139
Redlands Research Station	Oct 1990	181	938 (595-1429)	1.476 ± 0.217
Redlands Research Station	March 1991	181	699 (344-1415)	0.713 ± 0.092
Redlands Research Station	Nov 1991	239	278 (121-560)	0.686 ± 0.093
Wilson Farm	Jan 1991	180	804 (340-1687)	0.772 ± 0.118
Pongrazio Farm	Dec 1991	240	347 (172-632)	0.858 ± 0.111
Fischer Farm	Feb 1992	280	1470 (922-2395)	0.871 ± 0.092
Freeman Farm	Jan 1992	245	577 (340-955)	0.950 ± 0.105
Cross Farm	July 1992	240	1576 (839-2769)	0.975 ± 0.136
Granite Belt District				
Granite Belt Research Station	Dec 1990	207	165 (97-282)	0.895 ± 0.106
Poole Farm	Feb 1990	180	1208 (718-1994)	1.081 ± 0.128
Sweete Farm	Nov 1990	241	195 (92-368)	0.704 ± 0.106
Harslett Farm	Jan 1992	240	1028 (420-2556)	0.905 ± 0.140
Dixon Farm	Apr 1992	277	918 (564-1460)	0.897 ± 0.091
English Laboratory Strain	June 1993	280	47(28-80)	0.859 ± 0.083

Table 11: Methidathion

Collection site		**n**	**LD 50 (ppm)**	**slope ± s.e.**
Lockyer District				
Gatton Research Station	June 1990	152	462 (224-865)	0.929 ± 0.149
Gatton Research Station	March 1991	360	604 (447-830)	1.270 ± 0.111
Gatton Research Station	May 1991	178	697 (407-1186)	0.951 ± 0.131
Gatton Research Station	July 1991	172	556 (366-847)	1.454 ± 0.182
Diete Farm	Jan 1991	178	135 (72-218)	1.160 ± 0.203

Kanofski Farm	March 1991	177	51 (21-112)	0.663 ± 0.092
Jull Farm	April 1991	180	340 (218-539)	1.204 ± 0.157
Gatton Cooperative	May 1991	169	325 (197-536)	1.082 ± 0.151
Kamholtz Farm	July 1991	179	529 (317-824)	1.271 ± 0.191
Heisswolf Farm	Sept 1991	234	73 (24-143)	1.207 ± 0.249
Redlands District				
Redlands Research Station	July 1990	177	51 (29-90)	0.955 ± 0.118
Redlands Research Station	Oct 1990	210	67 (34-123)	0.925 ± 0.122
Redlands Research Station	March 1991	180	125 (58-243)	0.919 ± 0.137
Redlands Research Station	Nov 1991	282	385 (294-497)	1.940 ± 0.264
Wilson Farm	Jan 1991	177	526 (260-936)	1.147 ± 0.202
Moore Farm	March 1991	183	151(76-293)	0.838 ± 0.108
Pongrazio Farm	Dec 1991	243	89 (48-142)	1.066 ± 0.155
Fischer Farm	Feb 1992	242	184 (115-298)	1.041 ± 0.108
Freeman Farm	June 1992	232	280 (201-384)	1.692 ± 0.276
Cross Farm	July 1992	233	136 (89-206)	1.393 ± 0.177
Granite Belt District				
Granite Belt Research Station	Dec 1990	240	50 (32-78)	0.992 ± 0.118
Sweete Farm	Nov 1990	180	165 (114-240)	1.602 ± 0.209
Harslett Farm	Jan 1992	235	1043 (677-1693)	1.047 ± 0.117
Dixon Farm	Apr 1992	252	226 (128-377)	0.789 ± 0.098
English Laboratory Strain	June 1993	282	14 (9-21)	1.348 ± 0.169

Table 12: Mevinphos

Collection site		**n**	**LD 50 (ppm)**	**slope ± s.e.**
Lockyer District				
Gatton Research Station	June 1990	210	64 (30-131)	1.277 ± 0.268
Gatton Research Station	March 1991	174	424 (265-745)	1.273 ± 0.167
Gatton Research Station	July 1991	177	434 (279-670)	1.720 ± 0.247
Gatton Research Station	Sept 1991	223	39 (22-60)	1.430 ± 0.203
Diete Farm	Jan 1991	179	57 (37-85)	1.224 ± 0.163
Kanosfski Farm	March 1991	178	275 (190-419)	1.374 ± 0.179
Jull Farm	April 1991	363	104 (71-150)	0.961 ± 0.093
Gatton	May 1991	177	341 (204-517)	1.628 ± 0.877

Cooperative				
Kamholtz Farm	July 1991	173	52 (26-92)	1.022 ± 0.138
Redlands District				
Redlands Research Station	July 1990	184	62 (44-83)	1.898 ± 0.268
Redlands Research Station	Oct 1990	210	18 (7-49)	0.945 ± 0.152
Redlands Research Station	March 1991	171	182 (97-383)	0.782 ± 0.116
Redlands Research Station	Nov 1991	239	62 (37-96)	1.218 ± 0.178
Wilson Farm	Jan 1990	212	10 (2-32)	0.909 ± 0.199
Pongrazio Farm	Nov 1991	201	32 (23-40)	2.777 ± 0.464
Fischer Farm	Feb 1992	230	34 (12-66)	1.274 ± 0.238
Freeman Farm	June 1992	240	63 (38-96)	1.366 ±0.169
Cross Farm	July 1992	235	62 (42-91)	1.238 ± 0.109
Granite Belt District				
Granite Belt Research Station	Dec 1990	179	9 (6-13)	1.297 ± 0.183
Poole Farm	Feb 1990	176	86 (36-204)	1.430 ± 0.336
Sweete Farm	Nov 1990	177	111 (50-227)	1.301 ± 0.266
Harslett Farm	Jan 1992	245	57 (34-85)	1.697 ± 0.236
Dixon Farm	April 1992	233	31 (18-51)	1.360 ± 0.201
English Laboratory Strain	June 1993	282	1 (0.7-1.6)	1.127 ± 0.109

Table 13
Diazinon

Collection site		n	LD50(ppm)	slope ± s.e.
Gatton Research Station	March 1991	212	593223 (89140-139857162)	0.519 ± 0.137
Kanofski Farm	March 1991	179	89768389	0.313 ± 0.226
Redlands Research Station	March 1991	178	564215 (60527-919278880)	0.417 ± 0.121
Freeman Farm	June 1992	232	42612(18328-376294)	0.714 ± 0.199
Cross Farm	June 1992	231	253995 (66673-5432644)	0.615 ± 0.137

Table 14
Endosulfan

Collection site		**n**	**LD50. (ppm)**	**slope ± s.e.**
Lockyer District				
Brittingham Farm	Nov 1989	237	11189 (90-231093)	0.814 ± 0.329
Gatton Research Station	June 1990	293	1791 (1056-3141)	0.692 ± 0.083
Gatton Research Station	Mar 1991	264	8206 (4898-14924)	0.847 ± 0.097

Redlands District				
Redlands Research Station	Apr 1989	269	9357 (3322-34224)	0.521 ± 0.085
Redlands Research Station	Oct 1989	239	6879 (2360-18410)	0.683 ± 0.128
Redlands Research Station	July 1990	205	2034 (396-4557)	0.591 ± 0.148
Redlands Research Station	Oct 1990	180	12387 (4512-57313)	0.461 ± 0.089
Wilson Farm	Jan 1991	177	13784 (6679-31610)	0.635 ± 0.116
Freeman Farm	June 1992	236	7243 (3794-18233)	0.816 ± 0.178
Cross Farm	July 1992	237	29350 (14339-161925)	0.994 ± 0.241
Granite Belt District				
Poole Farm	Feb 1990	297	2297 (1218-4230)	0.747 ± 0.101
Sweete Farm	Nov 1990	179	7437 (3586-13102)	0.827 ± 0.133

Table 15

Collection site		**n**	**LD50. (ppm)**	**slope ± s.e.**
Carbaryl				
Redlands Research Station	July 1990	209	51084 (11738-836839)	0.351 ± 0.073
Poole Farm	Feb 1990	299	80988 (27776-514204)	0.499 ± 0.082
Freeman Farm	June 1992	251	1047706 (110216-90673437)	0.369 ± 0.099
Methomyl				
Gatton Research Station	June 1990	181	8196673	0.271 ± 0.208
Fischer Farm	Feb 1992	230	538607 (49642-1837512)	0.348 ± 0.106
Freeman Farm	June 1992	241	2960 (1872-4464)	1.310 ± 0.192
Cross Farm	July 1992	238	4567 (2368-9633)	1.069 ± 0.155
English Strain	June 1993	355	4.7 (1.5-12.5)	0.728 ± 0.127

Table 16
Populations of diamond back moth (*P. xylostella*) and cabbage cluster caterpillar (*C. pavonana*) on broccoli plants after a single spraying of a range of insecticides, Ormiston, October-November 1987.

Treatment	Concentration (ga.i./ha)	larvae/plant/days after spraying				
		-1	+3	+7	+14	+21
P. xylostella						
nil		24.6a	19.1a	10.3a	7.2a	12.2a
thiodicarb	131.3	20.0a	9.9b	6.5b	5.3ab	6.8b
"	262.5	33.0a	4.7bcd	4.0bc	4.5ab	5.3bc
"	375	23.7a	5.4bcd	1.4d	3.2bc	4.7bc
"	562.5	22.5a	5.6bcd	1.0e	3.1e	5.6bc
XGA 1115	30	19.7a	7.1bc	2.8cd	1.4cd	2.7cd
"	45	22.8a	3.9cde	1.2de	0.7d	1.4d
"	60	33,6a	3.5cde	1.1de	0.5d	1.6d
prothiofos	750	24.6a	0.6e	0.2e	0.8d	2.4cd
C. pavonana	(all instars)					
nil		2.2a	17.2a	34.4a	11.4a	37.0a
thiodicarb	131.3	3.3a	5.3bc	6.4bc	3.0a	15.2a
"	262.5	2.8a	4.2bc	1.3cd	3.0a	13.9a
"	375	0.7a	0.1c	0.1d	2.5a	20.5a
"	562.5	3.6a	0.0c	2.6bc	8.6a	8.5a
XGA 1115	30	4.5a	3.8bc	9.8b	6.7a	8.1a
"	45	7.1a	8.7ab	4.1bc	10.2a	26.0a
prothiofos	750	1.9a	0.1c	0.0d	4.9a	7.4a

Value, within columns, with common letters do not differ at the P=0.05 level of significance. All means are equivalent means, analysis used either the $\sqrt{x + 0.5}$, or log (x + 1) transformation.

Table 17

Log dose - probability regression summary for Forest Hill strain, June 1990.

Chemical	slope (± standard error)	Resistance Ratio (LD50)	Resistance Ratio (LD95)
Torque®	2.5 (0.35)	5.6	11.9
Omite®	2.5 (0.39)	2.0	5.2
Kelthane®	2.5 (0.36)	15.3	24.0
Nuvacron®	2.3 (0.12)	3,400	2,190.

Table 18
Percent mortality observed with *Tetranychus urticae* when sprayed with Torque® at the discriminating dose and x5, or x 10 the discriminating dose.

Strain	Concentration sprayed (% a.i.)	% Corrected mortality
Nobby Feb '90	0.003	77
(Granite Belt)	0.015	99
	0.03	98
Harrisville Mar'90	0.003	99
(Lockyer)	0.015	100
	0.03	100
Mt. Tarampa Apr'90	0.003	94
(Lockyer)	0.015	100
	0.03	100
Gatton June '90	0.003	94
(Lockyer)	0.015	100
	0.03	100
Grantham Aug'90	0.002	64
(Lockyer)	0.01	99
Gatton Sep '90	0.002	51
(Lockyer)	0.001	97
Larwes Oct '90	0.002	85
(Lockyer)	0.001	100
Ormiston Jan '91	0.002	21
(Redlands)	0.01	95
Ormiston Apr '90	0.002	91
(Redlands)	0.001	100
Winwill May '91	0.002	96
(Lockyer)	0.01	100
Ballandene May '91	0.002	95
(Granite Belt)	0.01	100
Wellington Pt. Sep '91	0.002	16
(Redlands)	0.01	50

Table 19
Percent mortality observed in *Tetranychus urticae* when sprayed with Omite® at the discriminating dose and x5 or x10 the discriminating dose.

Strain	Concentration sprayed (% a.i.)	% corrected mortality
Nobby, Feb'90	0.01	54
(Granite Belt)	0.05	95
	0.1	96
Harrisville, Mar '90	0.01	99
(Lockyer)	0.05	100
	0.1	100
Mt. Tarampa Apr '90	0.01	100
(Lockyer)	0.05	100
	0.1	100
Gatton, June '90	0.01	54
(Lockyer)	0.05	100
	0.1	100
Grantham, Aug '90	0.01	42
(Lockyer)	0.05	99
Gatton Sep '90	0.01	69
(Lockyer)	0.05	96
Lawes, Oct '90	0.01	69
(Lockyer)	0.05	96
Ormiston Jan '91	0.01	91
(Redlands)	0.05	100
Ormiston Apr '91	0.01	99
(Redlands)	0.05	100
Winwill May '91	0.01	98
(Lockyer)	0.05	100
Ballandene May '91	0.01	95
(Granite Belt)	0.05	100
Wellington Pt. Sep'91	0.01	43
(Redlands)	0.1	69

Table 20
Percent mortality observed in *Tetranychus urticae* when sprayed with Kelthane® at the discriminating dose and x5 or x10 the discriminating dose.

Strain	Concentration sprayed (% a.i.)	% Corrected mortality
Nobby Feb '90	0.01	17
(Granite Belt)	0.05	27
	0.1	41
Harrisville Mar '90	0.01	9
(Lockyer)	0.05	24
	0.1	60
Mt. Tarampa Apr '90	0.01	13
(Lockyer)	0.05	65
	0.1	97
Gatton June '90	0.01	11
(Lockyer)	0.05	27
	0.1	48
Grantham Aug '90	0.01	90
(Lockyer)	0.1	100
Gatton Sep '90	0.01	32
(Lockyer)	0.1	70
Lawes Oct '90	0.01	27
(Lockyer)	0.1	98
Ormiston Jan '91	0.01	52
(Redlands)	0.1	96
Ormiston Apr '91	0.01	3
(Redlands)	0.1	53
Winwill May '91	0.01	96
(Lockyer)	0.1	100
Ballandene May '91	0.01	98
(Granite Belt)	0.1	100
Wellington Pt. Sep '91	0.01	25
(Redlands)	0.1	45

Table 21
Percent mortality observed in *Tetranychus urticae* when sprayed with Nuvacron® at the discriminating dose and x5, or x10 the discriminating dose.

Strain	Concentration sprayed (% a.i.)	% corrected mortality
Nobby Feb '90	0.003	11
(Granite Belt)	0.015	27
	0.03	48
Harrisville Mar '90	0.003	8
(Lockyer)	0.015	23
	0.03	27
Mt. Tarampa Apr '90	0.003	9
(Lockyer)	0.015	24
	0.03	31
Gatton June '90	0.003	13
(Lockyer)	0.015	15
	0.03	13
Grantham Aug '90	0.003	16
(Lockyer)	0.03	56
Gatton Sep '90	0.003	26
(Lockyer)	0.03	88
Lawes Oct'90	0.003	64
(Lockyer)	0.03	92
Ormiston Jan '91	0.003	23
(Redlands)	0.03	41
Ormiston Apr '91	0.003	7
(Redlands)	0.03	7
Winwill may '91	0.003	14
(Lockyer)	0.03	28
Ballandene May '91	0.003	27
(Granite Belt)	0.03	98
Wellington Pt Sep '91	0.003	30
(Redlands)	0.03	25

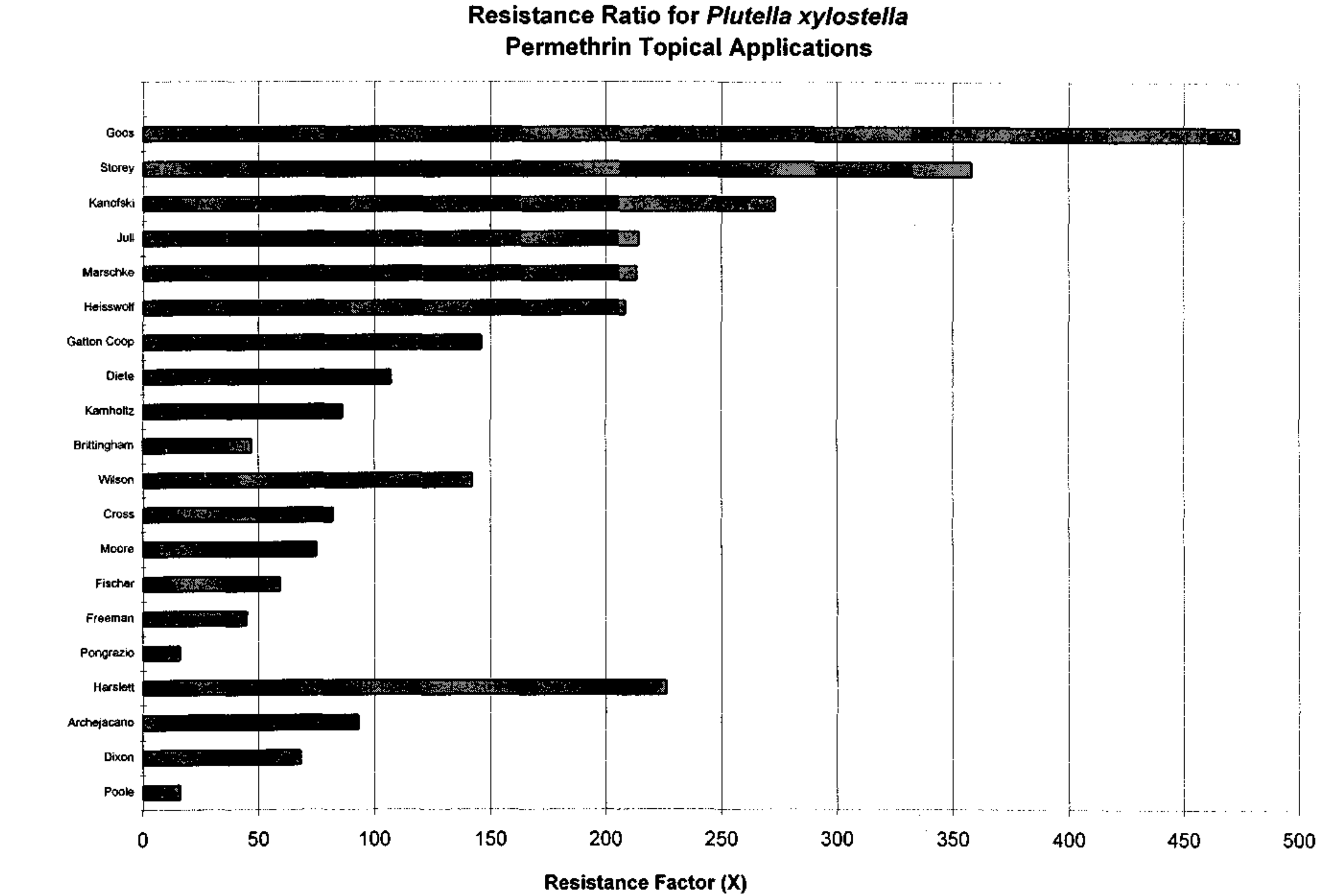


Figure 1 Resistance factor (x) for permethrin for each on-farm population compared with the susceptible English line

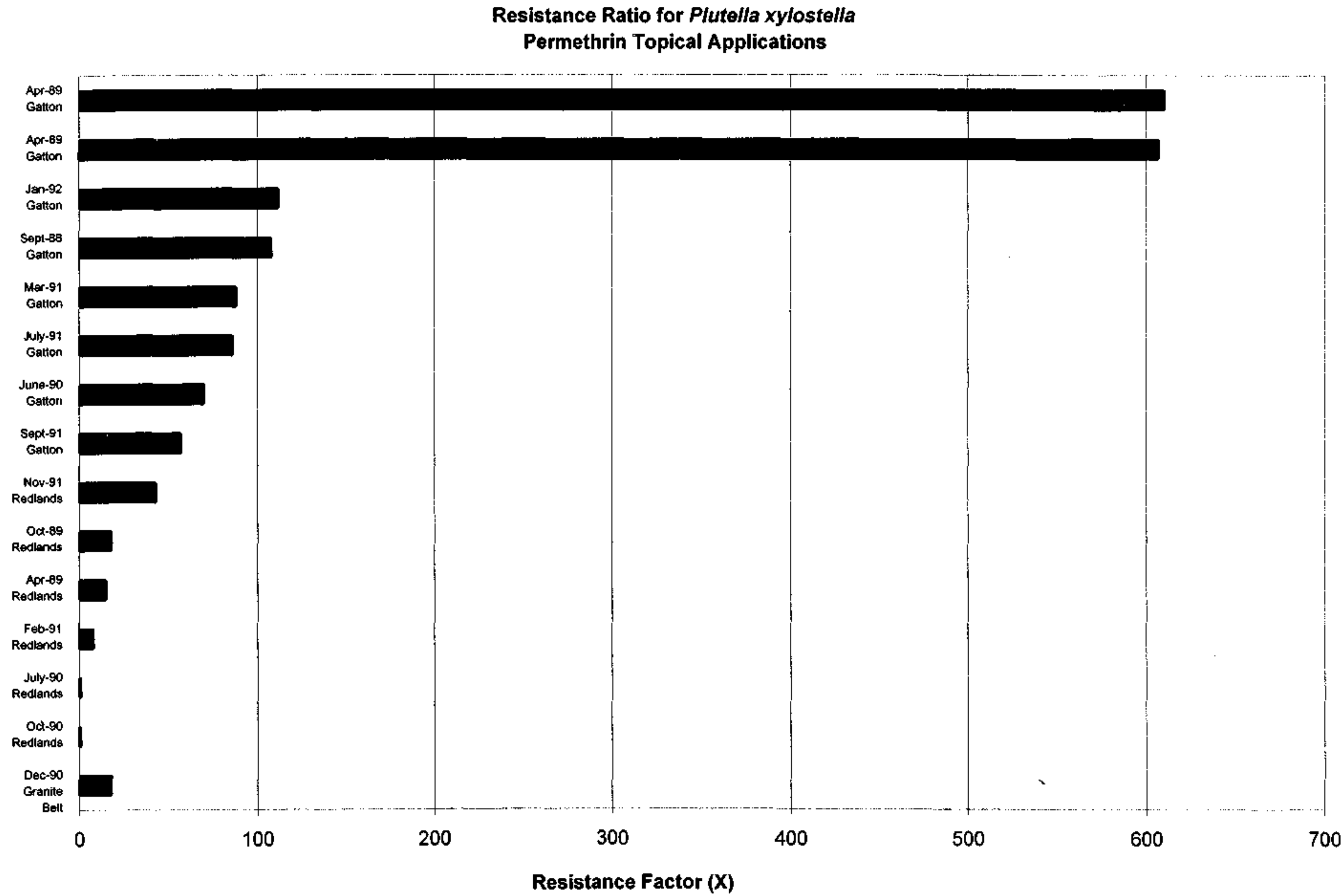


Figure 2 Resistance factor (x) for permethrin for each unsprayed sites' population compared with the susceptible English

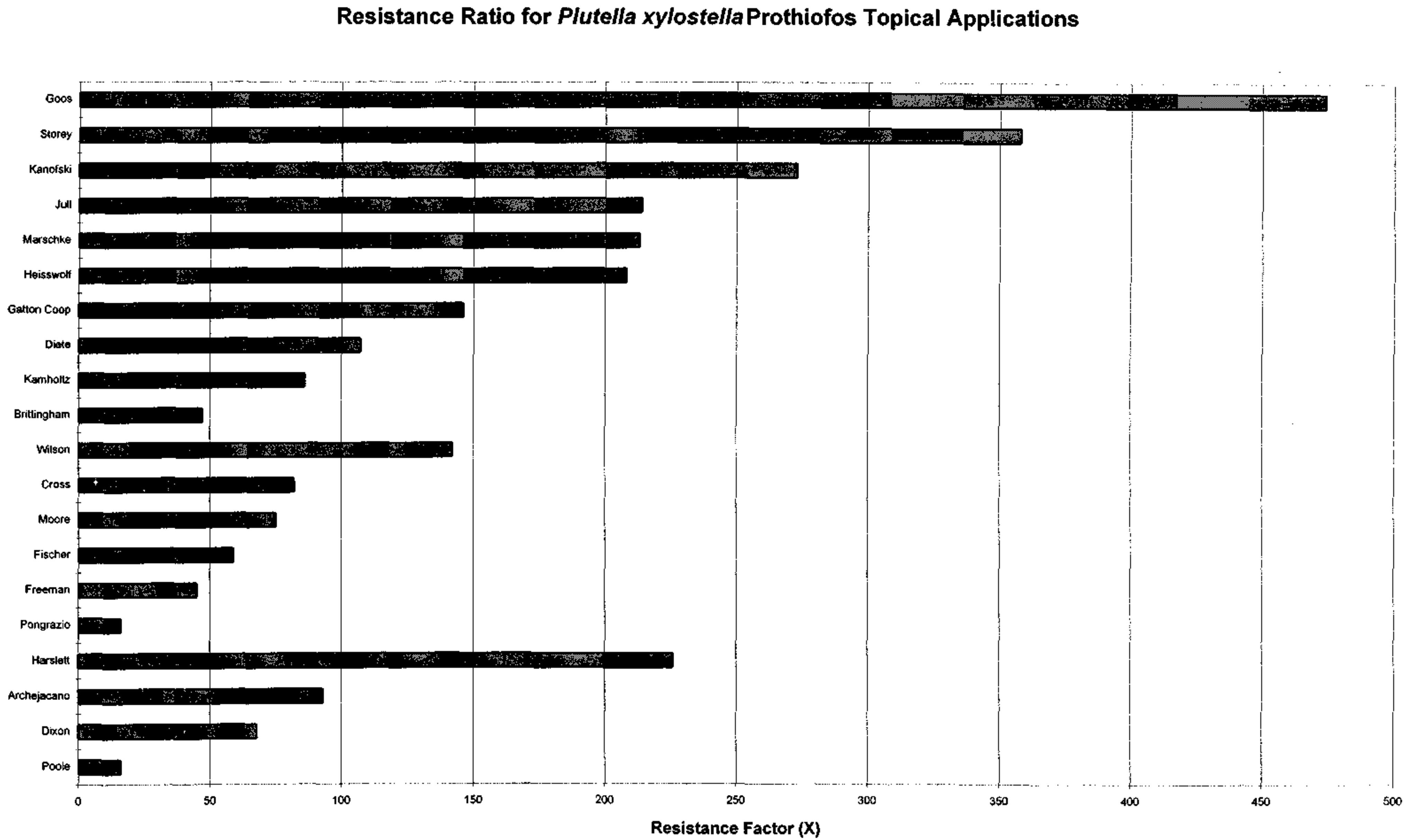


Figure 3 Resistance factor (x) of prothiofos for each on-farm population compared with the susceptible English line.

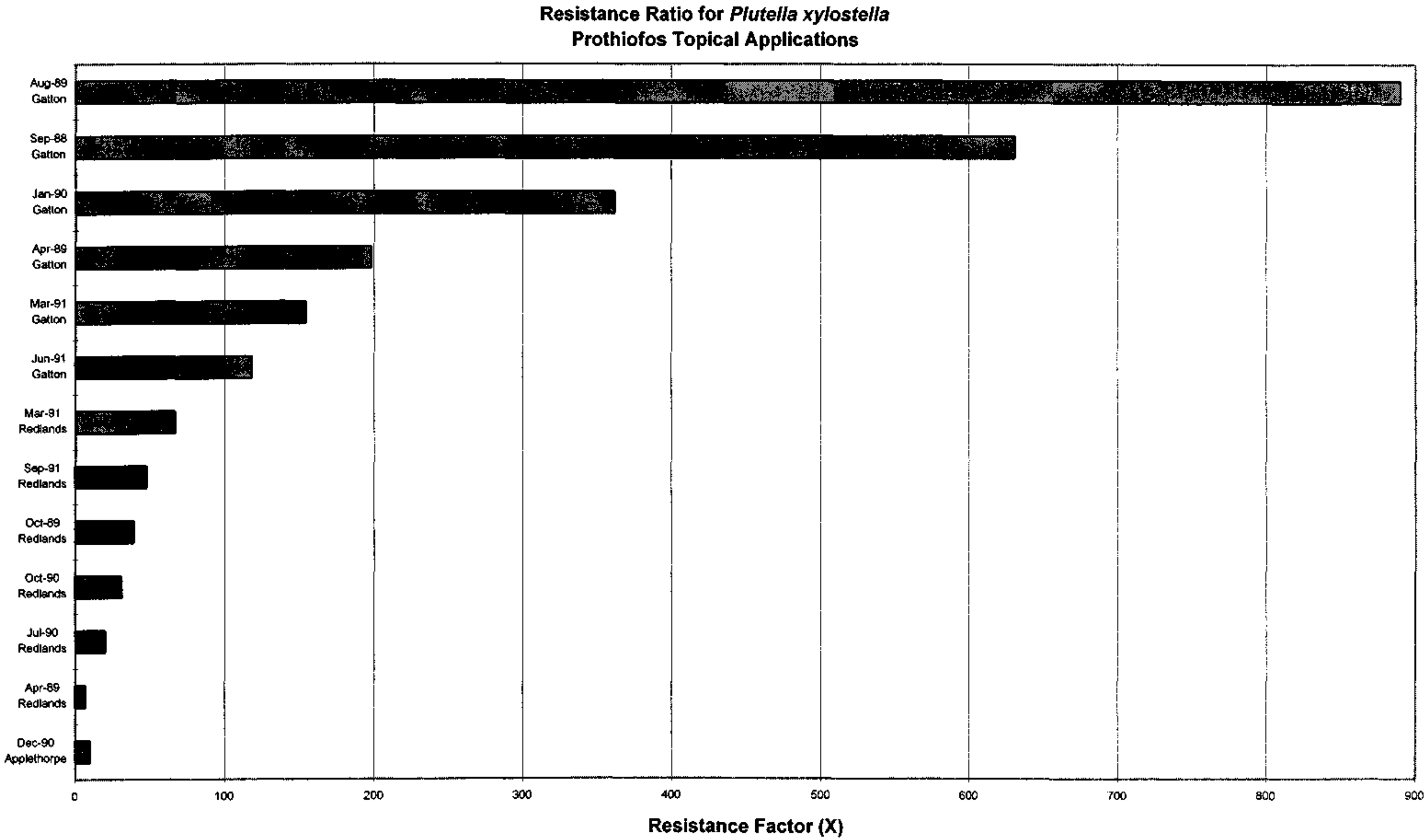


Figure 4 Resistance factor (x) for prothiofos for each unsprayed sites' population compared with the susceptible English line.

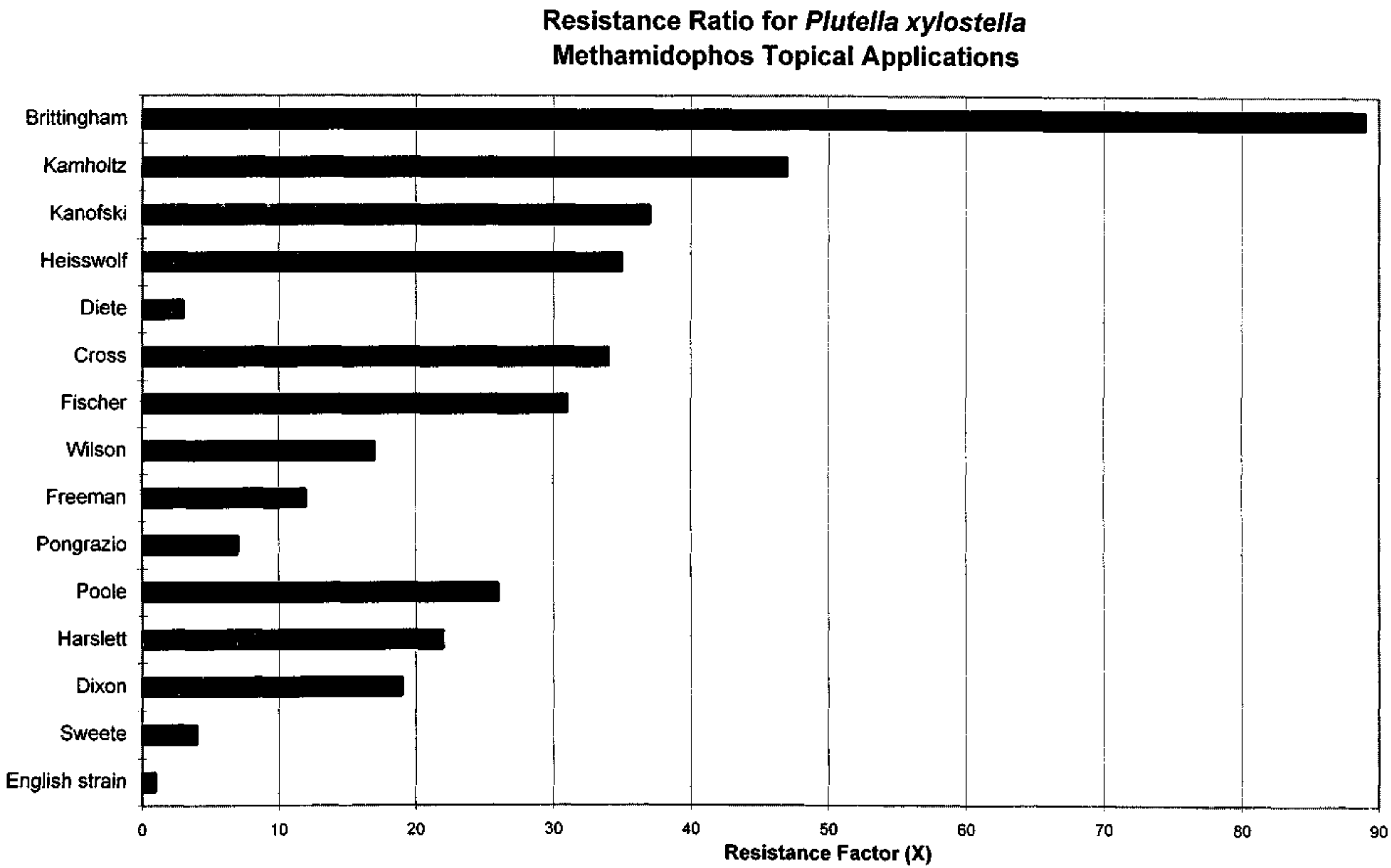
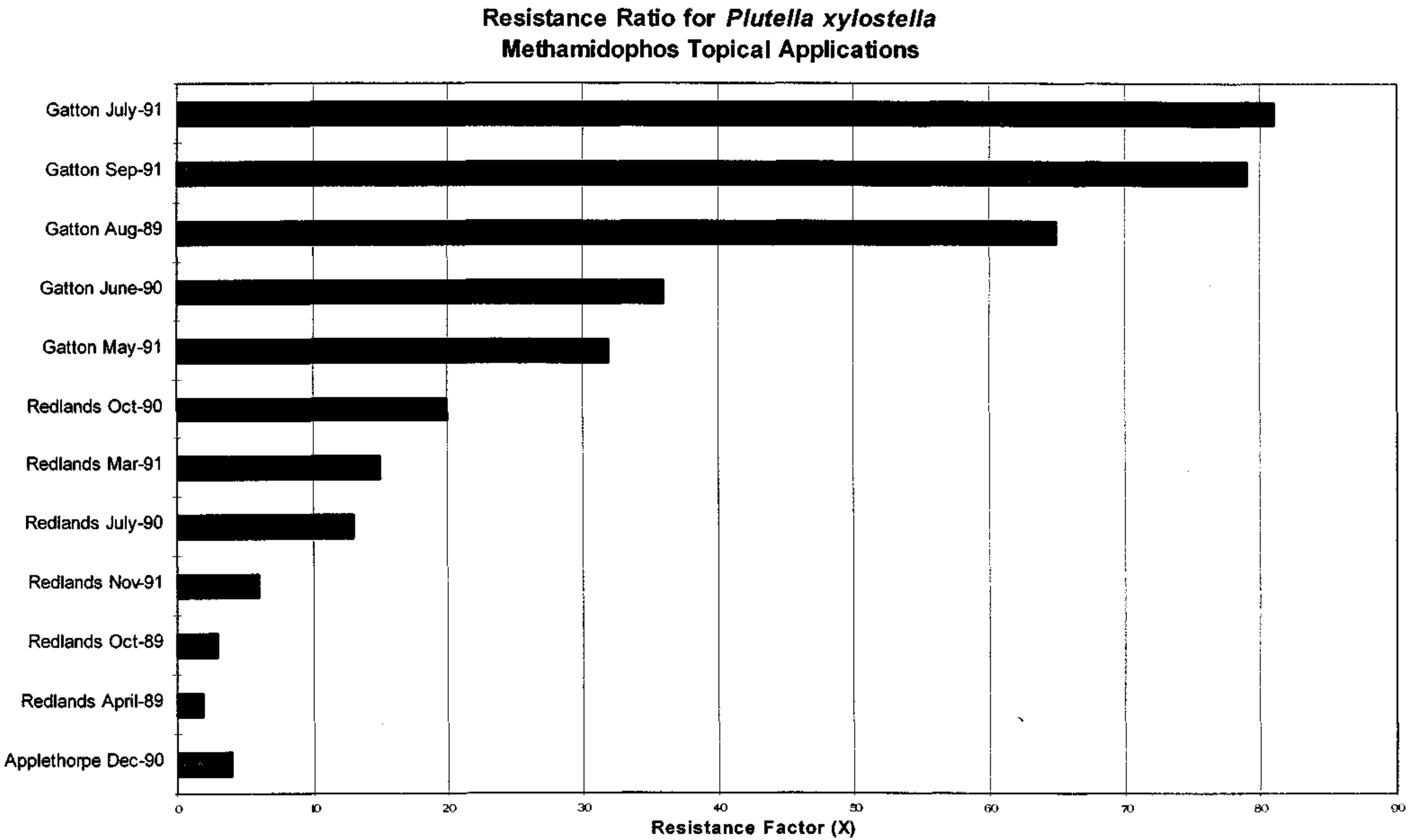


Figure 5 Resistance factor (x) for methamidophos for each on-farm population compared with the susceptible English line


Resistance Ratio for Plutella xylostella
Methamidophos Topical Applications
Gatton July-91
Gatton Sep-91
Gatton Aug-89
Gatton June-90
Gatton May-91
Redlands Oct-90
Redlands Mar-91
Redlands July-90
Redlands Nov-91
Redlands Oct-89
Redlands April-89
Applethorpe Dec-90
0
10
20
30
40
50
60
70
80
90
Resistance Factor (X)

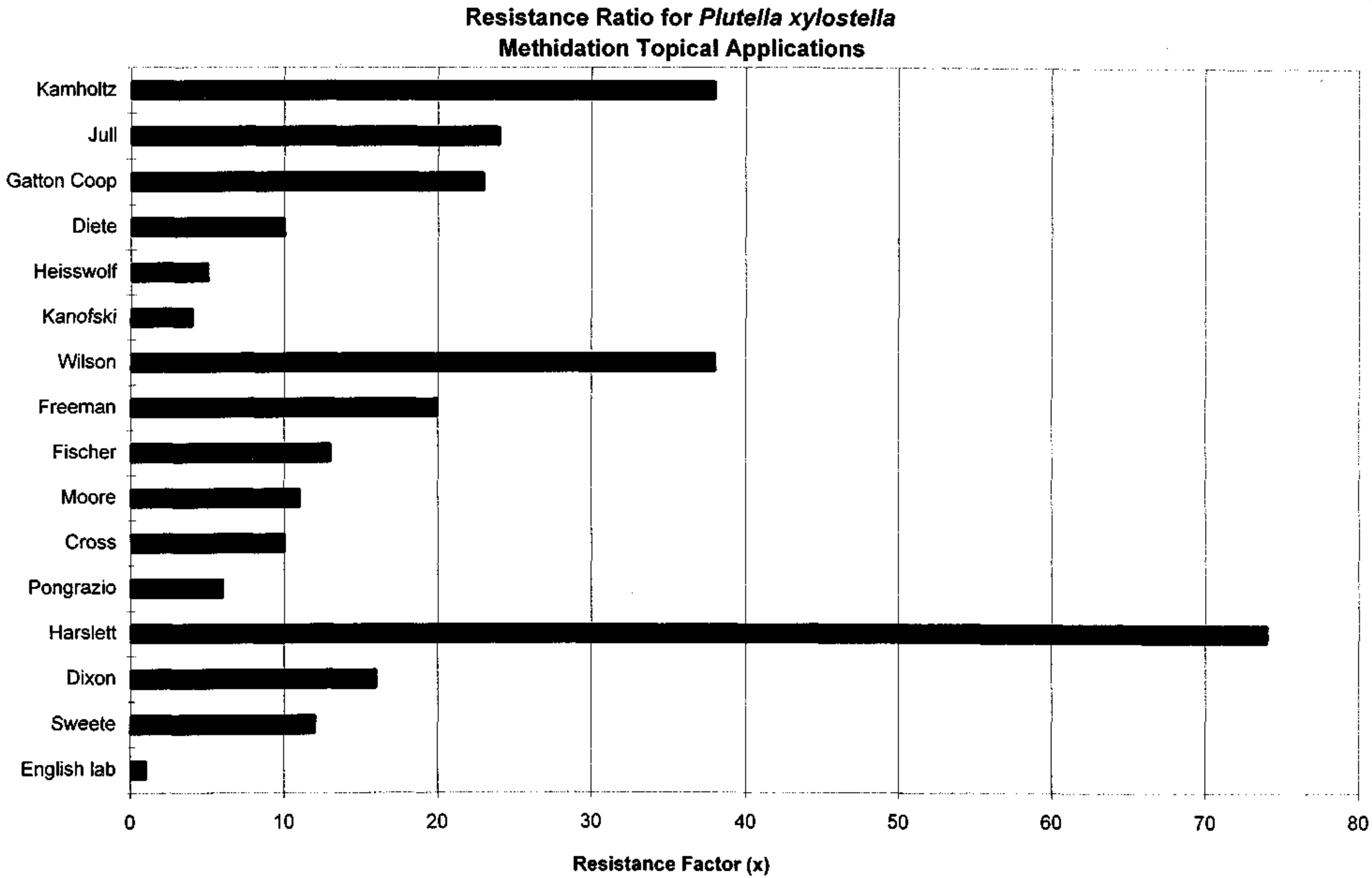


Figure 7 Resistance factor (x) for methidation for each on-farm population compared with the susceptible English line

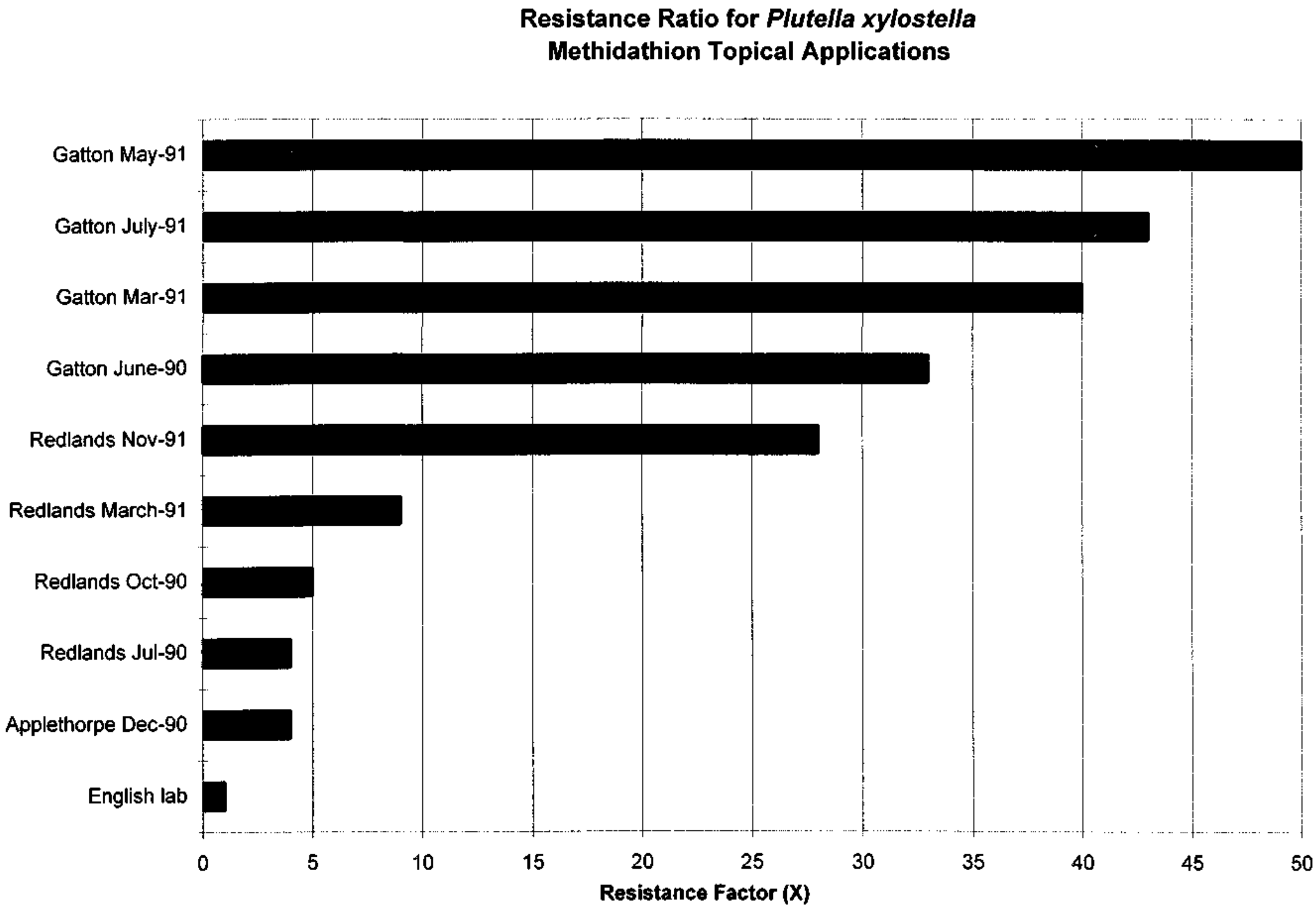


Figure 8 Resistance factor (x) for methidathion for each unsprayed sites' population compared with the susceptible English line

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APPENDIX 1

12 February 1991

Dr B. Cantrell
Manager (Horticulture Crops)
Entomology Branch
DPI
INDOOROOPILLY

MEMORANDUM:

HRDC PROGRESS REPORT

Please find attached the progress report and application for renewed funding for HRDC project No. V/0021/R1.

May I draw your attention to two aspects of the report.

(a) Level of industry support

I have not been informed of the level of COD support for the project for 1991 - 92. (I have heard rumours that COD Research Priorities Sub-Committee would like to reduce their contribution and confine activity to cabbage moth testing - but nothing official has been issued to me). Accordingly I cannot give a firm commitment in the report as to the exact level of voluntary contribution. I have adjusted the budget in case these rumours are true.

(b) Scrapping the aphid testing part of the work

I have mentioned the difficulty in getting aphids in the text and offer to leave at least $6 000 (one-third of $18 000) unspent in the fund. This amount should lapse back to HRDC and COD. The 1991 - 92 budget is also cut back to $9 900 which will allow both cabbage moth and mite dosing to proceed.

(J.R. Hargreaves)
<u>SENIOR ENTOMOLOGIST</u>
<u>ENTOMOLOGY BRANCH</u>

HORTICULTURAL RESEARCH AND DEVELOPMENT CORPORATION

I. GRANT APPLICATION 1991/92 — Continuing Project

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1. Project Title:

Insecticide resistance and insecticide management strategies for three vegetable pests in South East Queensland.

HRDC Reference No. V/0021/R1

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2. Organisation: Queensland Department of Primary Industries

Postal Address: G.P.O. Box 46, Brisbane Q 4001

Admin contact: Dr M. Bengston — Phone: (07) 8779350 — Fax : (07) 3710766

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3. Project Chief Investigators:

Dr P. Twine — Phone: (07) 8779352
Mr J. Hargreaves — Phone: (07) 2861488

Address: Meiers Road, Indooroopilly 4068; Delancey Street, Ormiston 4160.

Location of research:

Redlands Research Station, Cleveland — Phone: (07) 2861488 — Fax: (07) 2863094

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4. Commencement date: 1 July 1989

Anticipated completion date: 1 July 1992

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5. Total Project cost in 1991/92: $9 000.

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6. Synopsis

Vegetables are an important crop in Queensland. Development of insecticide resistance to two spotted mite and cabbage moth would result in low quality produce and/or unacceptable insecticide residues. The three valley insecticide strategy aims to delay such development. Measurement of insecticide resistance is fundamental to the success of the strategy.

7. Brief Statement of Objectives for Each Year of the Project

Year 1: Train casual assistant in collections, culturing and topical testing of insecticides. Assist with the establishment and maintenance of unsprayed plantings on research stations and collection from adjoining districts.

Year 2: Continue to sample from the three valley area and other areas when the pests are present. Compare with previous years and advise strategy organisers of any shift in resistance.

Year 3: Continue to sample from the area and compare any changes in pest susceptibility with agronomically related changes.

8. Industry Financial Support

Year	Voluntary contribution $	HRDC funds $	Project income $	Total $
1989/90	8 400	8 400	nil	16 800
1990/91	9 000	9 000	nil	18 000*
1991/92	4 860	4 860	nil	9 720
Total	22 260	22 260		44 520

* It is estimated that at least $6 000 will be returned unused to the funds in 1991.

PROGRESS REPORT

Achievements to Date

Cabbage moth

A table of LD50's for the strains tested is attached as Table 1. Three crucifer growing districts were sampled during the period. In one district, the strategy of rotation and break in production was promoted. In the two adjoining districts the strategy was not promoted.

One aim of the strategy has been to prolong the susceptibility of pyrethroid insecticides. Earlier work had shown a rapid rise in resistance to permethrin in the three valley area between 1985 and 1987.

Since the strategy, LD50 values have not increased beyond the 1987 levels, reaching a high in 1989. However the first district wide break in crucifer production occurred in summer of 1989-90. Consequent winter sampling showed a pronounced decrease in permethrin resistance levels. This drop also occurred in methamidophos and endosulfan figures and to a lesser extent with prothiofos.

The drop in resistance appeared unique to the three valley area. Adjoining Redlands and Granite Belt areas showed more uniform patterns of low level resistance.

Within the insecticides themselves, mevinphos and methidathion in the organophosphates and deltamethrin in the pyrethroids appear to be relatively more potent and could be promoted more. Conversely, endosulfan, carbaryl and methomyl appear weaker and could be restricted in their usage.

Dipping trials with methomyl against cabbage moth eggs (Table 2) give no support to methomyl's claimed ovicidal capacity against this pest.

Extension officers in the three valley area have been advised of the limitations of these insecticides.

Two spotted mites and green peach aphids

A summary of the miticide testing results of strains collected in the three valley area is attached as Table 3.

A general feature is the high level of resistance to the miticide monocrotophos and to a lesser extent to dicofol. Most strains appear quite susceptible to propargite and fenbutatin oxide. In view of the cost of testing, sampling of mites has been confined to the strategy area.

The searches for green peach aphids have been unsuccessful. Searching from commercial sites as well as providing stands of unsprayed or pyrethroid sprayed potatoes on research stations has given negligible yield of aphids.

It is recommended that this aspect of the work be abandoned. To this end, one-third of the monies allocated ($6 000) will not be spent and allowed to return to the fund.

ii) Objectives/Methodology Changes

(a) Abandonment of the testing for green peach aphids and commensurate reduction of funding.

(b) Establishment of additional unsprayed plantings of crucifers at Mutdapilly and Hermitage Research Stations.

iii) Research and Development Program

An article directed at restricting summer broccoli production in the three valley area was published in the Queensland Fruit and Vegetable News on 5 October 1989.

A review meeting with chemical resellers and extension personnel is to be held on 28 February 1991.

iv) Progress Summary

The levels of resistance of strains of cabbage moth have been monitored in three crucifer growing areas. Levels of resistance have been high in only one of these areas, (the three valley area incorporating the Brisbane, Lockyer and Fassifern Valleys). A strategy of insecticide rotation plus a district wide break in production was promoted in this district. Since the promotion, resistance levels have not increased substantially beyond pre-strategy levels. In addition after the first district-wide production break, resistance levels have dramatically dropped for most of the insecticides tested.

For two spotted mites, tested of three valley strains have shown an extremely high level of resistance to monocrotophos. High levels of dicofol resistance also occurred but most strains were susceptible to propargite and fenbutatin oxide.

The difficulty in obtaining sufficient green peach aphid colonies from the field has forced this aspect of the work to be abandoned.

Signature of Research Supervisor

Date

HORTICULTURAL RESEARCH &
DEVELOPMENT CORPORATION
The Research Arm of the
Australian Horticultural Industries

18 December 1991

Mr J Hargreaves
Entomology Branch
Department of Primary Industries
GPO Box 46
BRISBANE QLD 4001

Dear Mr Hargreaves

You may recall that early last year the Corporation undertook reviews of a number of projects. At the time you should have been informed that you would be notified of the outcome in due course.

For various reasons we are only now able to provide you with the Review Summary for your project(s) and you should find a copy enclosed. I appologise for this delay.

If you should have any questions regarding the Summary, or comments on the review process, please get in touch.

May I take this opportunity to thank you for your cooperation and patience. Could you pass on the Corporation's thanks to technical and administrative staff that were involved.

Yours faithfully,

Jolyon Burnett
Program Support Manager

Horticultural Research and Development Corporation Review of Research in Progress	
Project Title: Insecticide management strategies for 3 vegetable pests in SE Qld Project No. V/0021/R1 Project Year: 1990/91 *Chief Investigators: John Hargreaves*	Project Location: Redlands Review Date: 12.3.91 Reviewers: Davenport/Gregory
Are project objectives still consistent with the industry's R&D priorities?	Cabbage moth is the main problem – the other two pests were included at the request of industry. Future work will be devoted to the former.
Is progress of the project in line with the stated objectives?	The project has identified that the key to cabbage moth control is a 3 1/2 mth summer break from the growing of brassicas plus a planned, rotational program of pesticide use
Is the project running according to budget?	Yes – a reduced budget for 1991/92 of $9000 is planned & can be accommodated by concentrating on cabbage moth
Are there any staffing or equipment problems?	None reported
Is the scientific rigor of the project acceptable?	Yes – good progress has been made in developing control strategies & the difficulty is in gaining across the board grower involvement.
Are changes to the project required to improve its chances of success?	Two-spotted mite is not a problem with current insecticides – this with green peach aphid is being dropped from the project
Is there effective commuinication with industry?	Extension officers are evaluating grower response which in 1989 was 60%, dropping to 48% in 1990. The suggestion was made that recommendations to growers should be positive ie rather than "do not use this spray now" say "use this spray now"
Any other matters relevant to the progress of the project?	Will be looking at Insect Growth Retardents in future work eg diaphenthiuron (Ciba-Geigy) which reportably is good on cabbage moth & mites.

APPENDIX 2

JH:EMP
17 July 1991

17 July 1991

Dr Brian Cantrell
Manager
Entomology Branch
Department of Primary Industries
INDOOROOPILLY

MEMORANDUM:

BOARD APPROVAL No 61080

I would refer to the approved usage of methomyl for the control of eggs and larvae of cabbage moth, (*Plutella xylostella*) in brassica crops. This approval is listed as No 61080 in the 1989 Infopest information book, (copy enclosed).

I would ask if this usage might be reviewed. Please find enclosed data which would suggest that methomyl is not a good control for *P. xylostella*.

Egg dipping trials with formulated methomyl as well as serial dosing of third instar larvae with technical grade material have shown a very indifferent response to this insecticide.

Other carbamate insecticides such as carbaryl and thiodicarb were also unresponsive.

When I worked with methomyl on field trials in brassicas in the early 1970's, I found it hard to control *P. xylostella* larvae. This information was passed to Du Pont via conversation with Mr Geoff Campion. Du Pont had difficulty with methomyl in other locations and later took *P. xylostella* off their label registration.

This difficulty, as well as the high dosage of thiodicarb needed for field control, was mentioned to Dr Twine when the initial board approval application was being formulated. However Mr Shane Gisford, a Lockyer bugchecker was enthusiastic for methomyl as an ovicide for cabbage moth. This as well as our ignorance of methomyl's ovicidal capacity for *P. xylostella*, coloured judgement.

In view of consequent evidence, might the approval be reviewed?

Computer printout attached also

(J. Hargreaves)
<u>SENIOR ENTOMOLOGIST</u>
<u>ENTOMOLOGY BRANCH</u>

Table 1 Hatch 0-24 hour old eggs of *P. xylostella*, dipped for five seconds into a range of formulated insecticides and allowed to develop for a further 72 hours at 27°C.

Treatment	% eggs hatched	Number of 1st instar larval mines/leaf disc
Trial 1		
Nil	96.3 a	15.6 a
methomyl 11.3 g/100 L	98.5 a	13.8 a
methomyl 22.5 g/100 L	99.2 a	14.4 a
methomyl 45 g/100 L	98.0 a	11.6 a
methomyl 90 g/100 L	94.5 a	11.8 a
azadirachtin	98.6 a	13.2 a
Trial 2		
nil	99.4 a	7.9 a
methomyl 45 g/100 L (Kipsin)	100 a	6.9 a
methomyl 45 g/100 L (Lannate)	99.5 a	7.6 a
methomyl 45 g/100 L (Nudrin)	98.2 a	5.7 a
deltametherin 12.5 g/100 L	98.3 a	0.2 b

Table 2

Chemical	Population	n.	LD 50 (95% FL) (ppm)	Slope ±SE
methomyl	Gatton R.S., June 1990	182	8,196,672	.27 ± .21
carbaryl	Poole Farm, Feb. 1990	299	80,988 (27,776 - 514,204)	.49 ± .08
	Redlands R.S., July 1990	219	51,084 (11,739 - 856,839)	.35 ± .07
mevinphos	Gatton R.S., June 1990	210	64 (30 - 131)	1.27 ± .27

Table 3 Populations of diamond back moth (P. xylostella) and cabbage cluster caterpillar (C. binotalis) on broccoli plants after spraying with a range of insecticides, Ormiston, October-November 1987.

Treatment	Concentration (g a.i./ha)	Larvae/plant/days after spraying				
		-1	+3	+7	+14	+21
P. xylostella						
nil		24.6 a	19.1 a	10.3 a	7.2 a	12.2 a
thiodicarb	131.3	20.0 a	9.9 b	6.5 b	5.3 ab	6.8 b
"	262.5	33.0 a	4.7 bcd	4.0 bc	4.5 ab	5.3 bc
	375	23.7 a	5.4 bcd	1.4 d	3.2 bc	4.7 bc
	562.5	22.5 a	5.6 bcd	1.0 e	3.1 bc	5.6 bc
XGA 1115	30	19.7 a	7.1 bc	2.8 cd	1.4 cd	2.7 cd
	45	22.8 a	3.9 cde	1.2 de	0.7 d	1.4 d
	60	33.6 a	3.5 cde	1.1 de	0.5 d	1.6 d
prothiofos	750	24.6 a	0.6 e	0.2 e	0.8 d	2.4 cd
C. binotalis (all instars)						
nil		2.2 a	17.2 a	34.4 a	11.4 a	37.0 a
thiodicarb	131.3	3.3 a	5.3 bc	6.4 bc	3.0 a	15.2 a
	262.5	2.8 a	4.2 bc	1.3 cd	3.0 a	13.9 a
	375	0.7 a	0.1 c	0.1 d	2.5 a	20.5 a
	562.5	3.6 a	0.0 c	2.6 bc	8.6 a	8.5 a
XGA 1115	30	4.5 a	3.8 bc	9.8 b	6.7 a	8.1 a
	45	7.1 a	8.7 ab	4.1 bc	10.2 a	26.0 a
	60	2.1 a	1.9 c	3.1 bc	20.1 a	6.7 a
prothiofos	750	1.9 a	0.1 c	0.0 d	4.9 a	7.4 a
C. binotalis (less first instars)						
nil				18.7 a	5.6 a	20.4 a
thiodicarb	131.5			1.3 bc	0.7 b	10.0 a
	262.5			0.5 bc	0.0 b	12.8 a
	375.0			0.1 c	0.0 b	14.3 a
	562.5			0.2 c	0.0 b	7.7 a
XGA 1115	30			5.2 b	0.4 b	3.7 a
	45			0.7 bc	0.3 b	7.0 a
	60			0.6 bc	0.6 b	2.5 a
prothiofos	750			0.0 c	0.3 b	4.5 a

Value, within columns, with common letters do not differ at the 5% level of significance.

All means are equivalent means, analysis used either the $\sqrt{x + 0.5}$, or log (x +1) transformation.