VG412

Strategic Use of Pesticides as part of IPM Programs for Vegetables

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University of Queensland

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VG412

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HRDC PROJECT VG412

"Strategic Use of Pesticides as part of IPM Programs for Vegetables."

FINAL REPORT

BY

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INDUSTRY SUMMARY

The careful and strategic spraying of vegetable crops in the tropics and subtropics is important to minimise the contamination of the in crop and adjacent environment. Strategic use of pesticides also minimises the adverse effect of products on beneficial arthopods and reduces the opportunity for development of pest resistance to pesticides.

Investigations of the performance of hydraulic nozzles, their arrangement on spraying equipment and the use of air assistance have shown that equipment can be setup to strategically spray appropriate targets in crops. Capsicum and trellised tomatoes are different targets and the equipment needs to be setup appropriately to treat particular targets in each type of crop canopy.

Levels of pest activity and crop damage were generally lower in the treatments combining strategic pesticide use with living mulches than in conventionally treated plots with no mulch. The plot sizes used in the investigations were large and the final assessment for treatments was the commercial yield.

The strategic use of pesticides in both tomato and capsicum crops, rather than blanket spraying of the crop canopy and the inter-row spaces, resulted in yields of 1st grade fruit equal to or better than blanket sprayed treatments. Strategic spraying also requires less pesticide and less carrier to achieve an equivalent commercial result. This results in savings in time, wear and tear on equipment and total quantity of pesticides used.

The results of the project were discussed with producers in the major vegetable production areas of Queensland and they have had an impact on commercial crop production practices. Some capsicum growers in Bundaberg/Childers now incorporate living mulches and strategic spraying into commercial cropping practices. The major tomato growers have modified sprayers to allow pesticides to be used strategically, particularly targeting the tops of bushes for heliothis management as a distinct target area. Some larger stable platform sprayers have been completely re-equipped with nozzles, droppers and control systems to enable specific sections of the crop canopy to be sprayed strategically. Most sprayers are now accurately calibrated and the nozzles are changed appropriately. The use of global positioning systems on sprayers and advanced computer control are also increasing as producers now appreciate the need to very accurately position the sprayer in relation to the target.

The results of the project indicate:

- Strategic rather than blanket use of pesticides in vegetable crop canopies has advantages.
- Spraying equipment needs to be properly set up, maintained and calibrated.
- A stable spraying platform is essential for accurately targeting sections of the canopy.
- Air assistance can reduce inter-row contamination.
- Careful monitoring of pests and beneficials is important in the selection of the pesticide/s to be in a crop.
- Strategic pesticide use can conserve and enhance the activities of beneficials.
- The combination of strategic pesticide use with living mulches/companion plantings in the inter-row and headland spaces, has considerable potential to reduce costs, minimise pesticide use and support sustainable vegetable production in the tropics and sub-tropics.

TECHNICAL SUMMARY

Spraying Equipment

Most spraying equipment is poorly set up, maintained and calibrated. The sprayers used in this work had to be completely reconfigured with new nozzles. The nozzles used were selected after careful analysis of the droplet spectrum produced by hollow come nozzles at 5, 7 and 10 Bar.

Nozzles with a droplet round of 100µm and a span of approximately 1.6 at 5 Bar being the preferred for the application of insecticides/fungicides to the crop canopy. The use of air assistance can increase the penetration of droplets less than 150µm into the crop canopy.

However in some situations this may not be desirable because of the impact of some pesticides on beneficial organisms. The tomato sprayer was set up, after initial investigations, without air assistance. The capsicum sprayer was tested in trials with and without air assistance. In the large scale field trials it was operated with air assistance as this was the growers current practice and the use of air did minimise the inter-row contamination, particularly after the nozzle configuration was properly adjusted to target the crop canopy. The accurate control of sprayer speed and the location of the nozzles in relation to the crop canopy is very important in the strategic application of products to the canopy particularly in trellis tomatoes. As a result of this investigation sprayers are being fitted with computer control systems and global positioning systems. This will ensure the precise location and speed of travel of the sprayers.

Strategic Spraying

In both tomato and capsicum production the strategic use of pesticides has been shown to result in equivalent or higher yields of first grade fruit than conventional practices. The large scale field trials carried out in commercial crops have also shown the potential for combining the strategic use of pesticides with release/application of biological control agents/products and living mulches/companion plantings. Continuous professional monitoring of pests and beneficials is essential to support decisions including the pesticides to be used and what the real targets are in the crop canopy area. Particular attention must be paid to the pest/beneficial ratio and the overall population trends to support strategic pesticide use decisions. The involvement of professional plant IPM consultants is important as most producers do not have the skills or the time to ensure that IPM strategies involving strategic use of pesticides are implemented. Leafminer is a particularly important pest of tomatoes in the Bundaberg/Childers region causing considerable losses particularly where total canopy spraying with mixtures of insecticides is practiced. In strategically sprayed crops the incidence of this pest is very low because of the increased activity of biological control agents.

The results clearly show that targeting section of the crop canopy, the top third for *Heliothis* management, is an effective strategy in tomatoes. In capsicums it is difficult to target sections of the canopy individually because of the plant structure. In crops of this type the inner and outer sections of the canopy may be separate target areas.

Future Opportunities

For each type of crop canopy and pest/beneficial complex it is possible to develop pesticide use strategies using the principles and examples developed in this project. Information on the operations of pesticide application systems and the catching efficiency of droplets in canopies is available, has been used in this project and can now be applied to each cropping system pest beneficial complex. Agrochemical companies are increasingly providing information on the full activity of pesticides and droplets and their behavior.

Adoption of Research Findings

Tomato and Capsicum growers have adopted and put into practice the results of this project. Sprayers have been modified to direct sprays to particular targets, nozzles selected and operated at pressures to deliver the appropriate droplet spectra: SP Exports have further developed their large stable tomato spraying platforms by fitting advanced sprayer control systems and global positioning systems. Capsicum growers have redesigned their sprayers to target the crop canopy and particular growers use air assistance to minimise inter-row contamination and maximise canopy capture of sprays. Capsicum and Tomato growers now use companion plantings/living mulches to varying levels in crop production.

Don Halpin has developed a mechanical system for planting the companion planting at mulch laying. There is now considerable interest in incorporating companion plants/living mulches into vegetable crop production practices. Further development of suitable species and the set up of appropriate sprayers is an area requiring further research. This will support the further adoption of these development as part of sustainable vegetable production.

Vegetable growers in South Australia and Victoria have expressed interest in the results of this project. Government Departments particularly Department of Natural Resources and Department of Primary Industries visited project plots expressing interest and have followed up the efforts of leading growers to adopt and implement the outcomes. Consultants, Crop Tech in Bundaberg and Bowen Crop Monitoring Services are involved in assisting producers to implement the findings of the research to date.

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1.0 INTRODUCTION AND REVIEW OF LITERATURE

This project set out to investigate the potential for refining and targeting the use of pesticides as part of Integrated Pest Management strategies in sub tropical/tropical vegetable production. While pesticides are an essential element of successful vegetable crop production, their impact on beneficial and non-target areas needs to be minimised. If this is achieved, then the appropriate inclusion of pesticides in IPM will be ensured and the development of pest resistance and off target losses minimised.

1.1 Integrated Pest Management and Pesticides in the Environment

Integrated Pest Management (IPM) had as its foundation in Integrated Pest Control and was defined as *"all the different* ways *in which* a *pest can be controlled and to combine them harmoniously into* a *sensible pattern'* (FAO, 1971). It has since evolved into Integrated Pest Management that may be defined as " *a system that implements* pest *management practices that satisfy the farmer, consumer, governments regarding crop losses or a reduction in crop quality whilst at the same time, safeguard against long and short term risks of environmental pollution health hazards and agricultural sustainability"* '(Norton and Munford 1993).

IPM includes the use of physical, mechanical, cultural, varietal, quarantine, biological and chemical control methods (Harden, 1994). IPM should be orientated to prevent pest outbreaks by improving the stability of the agro-ecosystem rather than trying to control pest problems as they occur, (Altieri, 1987).

In an agro-ecosystem the use of pesticides to control pests is likely to negate the biological balance established. IPM stresses the importance of the use of both pesticides and natural enemies of pests (Hull et al. 1985).

For an IPM program to be successful it is necessary to consider the interaction of the pests, natural enemies, pesticides and the cultural practices used (Hull et al. 1985) With the development of IPM it has become increasingly important to evaluate the effects that pesticides are having on beneficial arthropods and to develop methods that minimise those effects (Greathead, 1995). There is little doubt that pesticides have been mismanaged and used in environmentally unsound ways (Metcalf and Luckman, 1994). Due to the ease of use, effectiveness and relatively low cost , growers have used pesticides as the principle form of pest control and stopped using environmentally sound biological methods which require prior planning (Metcalfe and Luckman, 1994).

Pesticides affect arthropod pest populations in two ways, firstly they kill the target pest, and secondly they may kill any beneficial arthropods that co-exist in the area. The destruction of beneficial arthropod populations results in the pest species population increasing and the net effect of the pesticide is much less than it initially appears (Wage, 1989). Not all insects receive a fatal dose of pesticide during application however, sub-lethal doses can have adverse effects on arthropod fecundity, longevity and development (Greathead, 1995). This particularly applies to beneficials which are generally more susceptible to sprays than the pest species (Hardin *et al.* 1995, Croft 1985).

Arthropods are extremely adaptable organisms and are able to overcome many obstacles that may be detrimental to their existence. Arthropod adaptability is demonstrated in their ability to overcome natural variations in climate and environmental conditions. When using pesticides, only susceptible arthropods are eliminated and resistant or tolerant individuals remain. A natural selection pressure is exerted to develop resistant populations (Pedigo, 1991).

Resistance is one of the most serious problems with the continued use of pesticides. Many arthropod pest species have exhibited resistance to both single and multiple chemical families. The ability of insects to survive pesticide treatments of the same chemical group or family is known as cross resistance (Metcalf and Tuckman, 1994). Cross resistance stems from a common detoxification system or from target site insensitivity. Resistance to multiple chemical families (multiple resistance) is far more critical, and often more difficult to deal with as the different chemical families have different modes of action and different detoxification pathways. Once resistance to a chemical has been acquired by an insect that resistance persists for an indeterminable length of time in future generations (Metcalf and Luckman,1994)

Resistance is acquired via a number of mechanisms within an insect including:

a). Metabolic resistance which is the breakdown of the active molecule by enzymes and

b). Knockdown resistance which is a result of reduced target site sensitivity of the sodium channels of the nerve axon. It is this mechanism that has led to resistance to Pyrethroids and DDT (Metcalf and Luckman, 1994).

Arthropod resistance development is dependent on a number of factors which include reproductive behavior, life cycle development and maturation rate. Pesticide application methods and chemical characteristics such as persistence and mode of action are more easily controlled and strategies to combat resistance should be based upon these characters. (Graham-Bryce, 1987). As resistance to a chemical is based on more than one single factor it is difficult to base resistance management purely on mode of action or the chemical class to which the chemical belongs

1.2 Pest Resurgence

Pest resurgence occurs when the beneficial arthropod population in an agro-ecosystem is eliminated (Van Den Bosch *et* al. 1973). Following the application of a pesticide treatment the pest population is controlled as well as any beneficials that are present in the field. As the effects of the pesticide begin to dissipate the pest population begins to increase, the natural enemies of the pest however, do not increase in population as their life cycle requirements differ significantly from those of their prey (Van Den Bosch et al. 1973).

It is believed that natural enemy mortality is the primary cause of pest resurgence as natural enemies are often more susceptible to pesticides than their prey. This can be attributed to:

a) differences in the detoxification abilities of natural enemies form their herbivorous prey;
b) concentration of pesticides due to biological accumulation
c) increased exposure to pesticides due to greater mobility and;
d) the inability of natural enemies to develop resistance as easily as their hosts (Hardin *et* al 1995).

The resultant change in ratio, induced by the use of pesticides, between natural enemies and pest species disturbs the balance that might have existed previously and leads to a population explosion, with numbers returning back to, or higher than, those originally found (Croft, 1990). Meerman *et al.* (1996) detailed the brown plant hopper formerly a minor pest in rice which has emerged to become the major pest of rice in tropical Asia over the last decade due to pest resurgence.

Even with the application of selective pesticides the loss of a host food source can lead to the starvation or migration of beneficial arthropods and cause a pest outbreak (Croft, 1990). Physiologically selective pesticides, chemicals that act on a specific point in a biochemical pathway, show promise in IPM systems provided that sufficient pests remain after application, to act as a food source for beneficials (Croft, 1990).

Resurgence tends to be restricted to a few groups of arthropod pests, notably Homopteran, Lepidopteran and mite pests. Resurgence is likely to occur only when the natural enemies that suppress the particular pest species are eliminated (Waage *1989).*

1.3 Effects of Pesticides on Beneficials

Most pesticides currently in use are broad spectrum in activity and affect beneficial insects in much the same way as they affect the target pest species. The beneficial population may be eliminated or severely reduced in a normal spray program and upon cessation of spraying may take years to re-establish (Cilgil *et al* 1993). The species that are likely to be the most severely affected in a full spray program are those that spend their entire life cycle in the field rather than emigrating to and from the field boundaries. Those that inhabit the plant surface rather than in or under the soil are also severely affected (Cilgil *et al.* 1993). There are several major differences between beneficial species and pest species that can be exploited to design control programs that will aid in the preservation of beneficial species. The strategic use of pesticides to conserve beneficials has a major part to play.

1.3.1 Susceptibility.

Beneficials may be affected by pesticides through direct contact with vapor or droplet fallout, uptake of pesticide residues or food chain transfer. The results of this contact may be lethal or non lethal and tends to reduce many of the arthropod normal functions. The level to which natural enemies are affected is determined by the characteristics of the natural enemy, the host or prey, the environment and the pesticide which was used (Croft, 1990)

The characteristics that enable natural enemies to withstand certain pesticides include size, weight, diet, previous exposure to toxins and development stage (Croft, 1990). Adaptation to toxic substances through the host may enable many natural enemy species to tolerate pesticides (Johnson, 1995). Some 30 species of natural enemies have shown resistance to pesticides however this tends to be of a temporary nature (Croft, 1990).

Dent (1991) determined that natural enemies were generally less susceptible to stomach poisons than their hosts and that they were less affected by systemic insecticides than the target pests. This has led to extensive research into selectivity. Pesticides can be selective in terms of the specific target site which they attack, physiological selectivity or in terms of their use, ecological selectivity in terms of where they are applied.

1.3.2 Physiological Selectivity

The physiological selectivity of a pesticide is dependent on either a reduced sensitivity in the natural enemy at the target site or an enhanced rate of detoxification in the beneficial compared to the pest species (Dent 1991). Sensitivity of an arthropod to the active molecule is highly variable between species and is dependent on a number of factors. These include:

a) The specific uptake mechanism of the active molecule
b) The metabolic processes involved and
c) The transport mechanisms used (Poeliling, 1989).

Phytophagous arthropods and predators although having similar dietary requirements consume foods that are nutritionally different. Phytophagus insects when ingesting their food source convert the methyl and ethyl groups in plant sterols into cholesterol. Predators are unable to perform this function and require an intake of cholesterol. By concentrating on this specific bio-chemical pathway insecticides that are specific to phytophagous arthropods only can be designed (Mullin et al 1985).

This is one of several bio-chemical pathways that are different between beneficial and pest species which can be used to develop selective insecticides. The difference between pests and their parasitoids is not as great however, thus making it extremely difficult to develop pesticides that distinguish between pests and their parasites are able to act against the pest species only (Croft, 1990).

It is unlikely that highly selective compounds will be developed on a large scale due to the high costs of development and the small markets that would be targeted. It is therefore more economically viable to alter the method and timing of application (ecological selectivity) to favor natural enemies in the agro-ecosystem.

1.3.3 Ecological Selectivity

Ecological selectivity involves the modification of application procedures, timing, formulation variation, application rate (Poehling, 1989, Johnson, 1995). The aim of ecological selectivity is to maximize pest mortality and minimise natural enemy injury so as to alter the pest/beneficial ratio in favor of the beneficials (Hull *et al. 1985)*. The development of these techniques has the greatest potential for pesticide selectivity in maintaining a beneficial population when using the broad spectrum chemicals currently available.

With the use of current application methods one of the most important tactics for selectivity is spray timing (Hull *et al.* 1985, Poehling, 1989), Pesticide applications should be restricted to periods of low beneficial activity, which may occur on a cyclical basis within the crop (Johnson, 1995). A thorough understanding of the pests and beneficials biology and life-cycle is required so that sprays can be timed to coincide with the particular life cycle stages at which the beneficials are least susceptible to the effects of sprays. This is particularly important with beneficials that have a holometabolous life cycle, as sprays can be timed to coincide with pupal and pre pupal developmental stages.

Sprays should be applied at the time of day, or the particular period within a season when beneficials are least active. Where possible treatments should be avoided during the middle of the day or during flowering periods when beneficials are most active (Dent, 1991). Spray applications should cease at designated times during the growing season when it is known that beneficials account for a high proportion of pest mortality. Applications during this time cause the loss of beneficials as well amounting to a waste in chemicals and unnecessary expense (Dent, 1991).

1.4 Strategic Application

The application of pesticides using conventional hydraulic equipment often results in drift being inadvertently deposited into areas immediately adjacent to the crop being sprayed. Only 20-50% of the spray applied reaches the surface of the crop with less than 1% actually coming into contact with the intended target organism (Metcalf and Luckman, 1982)

Restricting pesticide application to a particular plant part or field area will reduce off target damage and allow beneficials to remain within the agro-ecosystem (Hull et al. 1985). Strategic pesticide application (precise placement) can be used to prevent contamination of the living mulch and companion planting assisting in the maintenance of a beneficial arthropod population and a non resistant pest population in companion plants.

Strategic application can be combined with reduced dosage and non persistent chemicals to achieve control of pest species (Dent, 1991). Registered chemical dose rates are usually designed to give maximum kill rates even under the poorest of conditions (Poehling, 1989). At these high rates there is no selectivity however, it has been shown that by significantly reducing the dose rate and spraying when a pest is most susceptible then selectivity between pests and beneficials can be achieved (Poehling, 1989). When using lower dose rates it is unlikely that the pest population would be controlled to the same extent as when using the recommended rate. This however, maybe an advantage rather than a disadvantage. A surviving pest population provides a food source for beneficials and also dilutes the resistant proportion of the population thus slowing resistance development in the pest species (Dent, 1991).

It is essential in these programs to use non-persistent chemicals if possible. Beneficials are often able to survive pesticide applications in their resistant stages (pre-pupal or pupal) provided their are no residues present upon their emergence (Hull et al. 1985) This is also applicable to beneficials that take refuge in mulches. They are able to survive the initial pesticide treatment however, they may be susceptible to residues that remain on the plant leaf surface for any length of time after the application.

The combination of strategic use of carefully selected pesticides with the activities of beneficial organisms has considerable potential in modern vegetable production for reducing the problems currently caused by continuous use of pesticides.

1.5 This Project

This research project looking at strategic application has consisted of a number of interrelated investigations performed by several researchers. The major findings of these investigations have been brought together in this report. More information will be available on strategic spraying in tomatoes when the masters student investigating this area releases her thesis. A list of other reports from which the following information has been taken is available in Appendix 1.

2.0 MATERIALS AND METHODS

2.1 Strategic Application in tomatoes

2.1.2 Strategic versus Conventional Application

A pilot trial was conduced in the Spring season of 1994. The trial was designed to determine if strategic spraying offered advantages compared to conventional total crop canopy spraying in tomatoes. A stable spraying platform was configured with carefully selected hollow nozzles to allow sections of the crop canopy to be sprayed individually.

2.1.3 Trial area

The tomato crop used for the trial was on a property belonging to SP Exports located between Bundaberg and Childers. Floridade tomatoes were transplanted as seedlings into rows covered with plastic mulch. Wooden stakes placed 8 to 10 meters apart were used to support the trellis wires, which were added one by one as the crop increased in size. Usually 3-4 wires were needed, as the crop height averaged 1 to 1.2 meters. The tomatoes were grown in lands of 11 rows, with an access headland between each land. Harvesting usually continued over a 4-5 week period.

Four adjacent treatments were used, each of one sprayer width (5 ½ rows), with the four treatments together taking up 2 lands. The rows were approximately 200 meters long. Fungicides and herbicides were applied uniformly over the four treatments when required. Insecticide treatments (refer to Table 1) began when the crop was 4 weeks old.

Table 1: Treatments Applied

Treatment 1-	Bt Only	Bt applied as a whole canopy spray
Treatment 2-	Larvin Top Spray	Larvin applied as a top spray over a

		whole-canopy spray of Bt
Treatment 3-	Insecticide Mixture Top spray	A cocktail of insecticides, including Larvin, lannate, folidol and helithion was applied as a topspray over a whole-canopy spray of Bt
Treatment 4-	Insecticide Mixture Complete Spray	The same cocktail of insecticides as the top spray, including Bt, was applied as a whole-canopy spray

2.1.4 Spray Equipment

The stable platform sprayer used was designed to spray 5 ½ rows (half a land) at a time. Nozzles were arranged on droppers (5 nozzles per side for each dropper). The nozzles used were hollow cone D2's with 25 swirl plates. The sprayer was a stable platform rig with two tanks which were separately controlled by the driver. For experimental purposes, top sprays were directed at the top third of the bush.

2.1.5 Sampling

Sampling for arthropods (pests, beneficials, and general diversity) was carried out using commercial crop monitoring, destructive whole plant sampling and pitfall and sticky traps. Fruit yield and quality assessment was made during the period of commercial harvesting. A transect of the crop was used to monitor disease progression through the season, and weather data was obtained from the closest Meteorological Bureau station (Bundaberg Airport)

Destructive sampling was carried out twice during the growing period, with the bushes divided into top (top-spray area) and bottom. Fruit assessment coincided with the time of the second destructive sampling. The tomato bushes were destructively sampled in pairs to minimise plant interface disturbance. Pitfall and sticky traps were collected after 24 hours. Buffer areas were established at the ends of treatments and by using the outer two rows of each treatment.

2.2 Integration of Biological Controls into Tomato Production

To assess both the effectiveness and the susceptibility of biological controls to pesticides a *Trichogramma* spp. trial was conducted on SP Exports Pierson Homes Property in Bundaberg, Queensland. This trial was conducted in conjunction with Richard Llewellyn Bio-Protection Pty Ltd, Iain Kay QDPI Bundaberg, Croptech Research Bundaberg and John Harden University of Queensland Gatton.

Five treatment areas were in Block 3:

- Top Spray with Mulch
- Top Spray without Mulch
- Full spray with mulch

- Full spray without mulch
- Trich + Bt only with mulch. No insecticide for as long as practical.

Each treatment had four replicates. The crop area included in the trial was about 4 hectares. *Trichogramma* eggs were applied (with B.t.) Tuesdays and Fridays, weather permitting, at around 300,000 (6gms) of parasitised eggs per hectare per release.

Twenty five sentinel egg cards were placed in each replicate each week. Sentinel cards consist of a minimum of three freshly laid *Helicoverpa armigera* eggs on a small piece of cloth about 1 cm square stapled to a strip of paper about 1 cm by 5 cm which was then stapled to a leaf near the top of the plant. These egg cards enable large numbers of fresh eggs to be placed at the same density in each plot and then collected after two or three days. In this way, the parasitism in the plots can be compared knowing that all egg samples have been in the crop for the same length of time.

Once collected the egg cards are kept in a warm place and those parasitised are placed in separate glass vials. After the wasps emerge they are identified according general characteristics.

Pre-release samples were taken in the release Block 3. A similar aged crop nearby in Block 7 was used as a control in the early stages of the trial.

2.3 Nozzle Technologies - wear and droplet sizes.

The following hollow cone nozzles were tested at 5, 7 and 10 bar:

Table 2 : Nozzles Tested

Manufacturer	Model	Material	Angle if stated	No of sizes	Disc/core combinations or sizes
Lumark	Hollow cone tips	acetyl co-polymer		6	2/13, 2/23, 3/23, 2/25, 3/25, and 3/45
Spraying Systems	Teejet	ceramic		6	2/13,2/23, 2/25, 3/23, 3/25, and 3/45
Albuz (Hardi)	1299	ceramic		4	10(B1), 12, 14 and 16
Spraying Systems	Conejet TX	Ceramic	80	4	3, 4, 6, and 10
Spraying Systems	Conejet TX	brass	80	5	3, 4, 6, and 10

The following flat fan nozzles were also tested:

Table 3 : Flat fan nozzles tested

Manufacturer	Model	Material	Angle if stated	No of sizes	colours/size

Hardi	3110	ceramip tip	110	3	Green/1.4, orange/.70, yellow/.49
Lurmark	SD low drift	acetyl co-polymer	110	2	brown/015, orange/02
Lurmark	Std F110	acetyl co-polymer	110	2	orange/02, pink/01

In developing and refining application systems a wide range of nozzles have been evaluated. Features including droplet size and flow rates of new nozzles were examined in relation to spraying pressures. In particular nozzle wear and deterioration caused by abrasive pesticides such as copper fungicides was measured in commercial spraying situations. To determine nozzle characteristics a series of Malvern tests were conducted upon a commercial range of hollow cone nozzles to determine the effects of pressure upon droplet size and flow rates. The aim was to identify particular nozzles types and operating pressures which would give droplet spectrums with volume mean diameters of 80-100μm. These droplet sizes are optimal for high capture efficiency rates on foliage, flowers and young stems.

A Malvern B2600 laser particle analyser was used for testing of the nozzles as specified in Table 2. Using this equipment to measure droplet spectra is acknowledged as one of the accurate methods that use laser diffraction of light to measure droplet size. This machine includes sophisticated software that enables many measurements to be taken over a short period of time with accurate and repeatable results.

Previous testing had been undertaken at the University of Queensland using this machine with acceptable results. However no set protocol had been established for its use and this was seen as unacceptable if results for this project were to be compared over time. Previous testing had used statically mounted nozzles located approximately 5 cm from the laser beam and measurements were repeated five times to determine a mean reading.

The laser beam is thin and can only measure droplets passing through it from a relatively small area of the total spray cloud produced. Spray patternator tests on nozzles show that the volume of droplets produced from spray nozzles can vary considerably in different parts of the spray pattern produced by a nozzle. Initial testing using the Malvern to examine the variation did show that rotation of a static nozzle which was seemingly aligned to the centre produced significantly different outcomes. Tests involved multiple measurements of nozzles at different rotational positions at, above and below a central alignment, and included a comparison with individual nozzles of the same specification. All tests showed that the static method was inaccurate in predicting nozzle parameters and resulted in difficulties in obtaining repeatable results. A more objective test protocol was required.

Two possible protocols were considered:

1. a) Keeping the nozzle static and taking measurements at several points in the spray pattern to obtain data to calculate the mean. Five parallel cuts was suggested as being used in other testing procedures

   or,

   b) many cuts could be made by simply rotating a nozzle on its axis through the laser beam.

2. Moving the nozzle so that the whole spray pattern passed through the laser beam, this would result in measurement of the entire spray pattern and eliminate the need for repeated measurements to obtain the mean.

The first protocol 1(a) was rejected as it would be difficult to ensure that cuts were made in identical positions for different nozzles. There was also the difficulty of setting up a system to move the nozzle into the five positions in a consistent way. Protocol 1(b) was rejected as evidence showed that rays of denser spray may be produced in some sections of the nozzle pattern. If measurements were taken within this area a false value would be obtained. Essentially the spray pattern was not considered uniform enough and this would be very noticeable if nozzles other than hollow cone were used. Protocol 2 was adopted as the most appropriate producing consistent repeatable results with less room for error when using the protocol.

2.3.1 Protocol Used for Droplet Spectra Measurement

A sturdy frame was constructed on which a gantry holding the nozzle arm was mounted, the gantry was moved by a small electrical motor driving a chain to raise or lower the nozzle through the beam. The electrical motor is 12 volt and allows the gantry to be moved with as little vibration as possible. The rate of movement was 0.044m/sec in an upwards direction. All measurements were made with the motor under load moving upwards at a consistent speed. The speed was selected to ensure that the whole spray pattern passed through the laser in approximately 5 seconds. This results in the Malvern having time to make up to 2000 sweeps. Sweeps are individual measurements taken by the Malvern which are then averaged to form a mean, in essence 2000 measurements are taken of the droplets as the nozzle passes through the laser beam. Nozzles were positioned 7.5 cm from the laser beam to allow about 4 cm (varies with spray angle) of the beam to be active, the droplets were considered to be stabilised at this distance from the nozzle. Using this protocol nozzles were tested at 5, 7 and 10 bar with a pressure gauge mounted at the nozzle head for accurate recording. A small fan was also used to ensure that all droplets moved through the laser beam by air movement at the nozzle of 0.5 m/sec. This was particularly important for small droplets which otherwise tended to drift out of the measurement field if not assisted.

For each nozzle type at a given pressure, two replications of the measurement were made and five individual nozzles per type were tested. This gave a total of ten separate measurements each nozzle type and pressure of operation, for which the mean and standard deviation were then calculated. Previous extensive testing (up to forty replications) had shown through statistical analysis that two replications provided an accurate indication of the true mean.

2.3.2 Flow Rate Measurement Method

The flow rate for each nozzle tested was recorded by measuring the volume output of water which passed through a nozzle in 30 seconds. A single measurement was taken for each nozzle at each operating pressure tested. These measurements were conducted on a patternator machine with a high quality pressure regulating system. In the future it is envisaged that the flow rate may be recorded from a nozzle whilst actually running the Malvern test protocol, this was not possible in these tests.

2.3.3 Spray Angle Measurement Method

This measurement was also taken on the international standard patternator using a large protractor with a slide rule and sight alignment. To enable accurate measurement a strobe was used to highlight the spray pattern more clearly. A single measurement was taken for each nozzle at each operating pressure.

2.4 Impact of strategic pesticide use on the pest/beneficial ratios in inter-row plantings

2.4.1 Trial design, Sampling and Analysis

The trial consisted of 16 plots each being 96.5m in length, and 13.5m wide and included an access path. The following spray treatments were applied to the capsicum crop with white clover mulch: The treatments applied were:

Treatment 1. Twin hollow cone "albuz" yellow nozzles with air assistance;

Treatment 2. Twin hollow cone "albuz" yellow nozzles without air assistance;

Treatment 3. Single hollow cone "albuz" yellow nozzles with air assistance;

Treatment 4. Single hollow cone "albuz" yellow nozzles without air assistance

These treatments were applied to the capsicum crop with white clover mulch in the 4 blocks to allow comparison of the different spray treatments. White clover was selected for the application of treatments due to its long flowering period, perennial habit and suitability as a harbor for beneficials. White clover was seeded at a rate of 2 kg/ha. To ensure establishment seed was inoculated with *Rhizobium bradyrhizobium spp.* in a milled peat carrier before planting.

The white clover plots were subdivided into 4 subplots to allow spray treatments and analysis to be performed. The treatments were randomly applied to the 4 white clover plots within each block after subdividing .

The first investigation was performed in a mature capsicum crop without mulches in the inter-row spacings on the 31st August 1996. Each plot was 25m long with a 5m buffer zone established between plots to prevent contamination of one spray treatment into the other. Spray treatments were randomly assigned to each plot in each of the 4 blocks. The plots and buffer zones were marked using different coloured plot markers to identify the treatments to be applied. The spray rig used in the trial was a tractor drawn hydraulic boom sprayer with fans and air bags to increase spray penetration into the crop canopy running between the droppers.

Prior to spraying the plots the Spray rig was calibrated (figure 1). The calibration procedure was accomplished firstly with all nozzles operating at a pressure of 4 Bar.

The calibration was then repeated with selected nozzles blanked off, and the remaining nozzles operated at 4 bar operating pressure to determine the output when using single nozzles. It was necessary to perform the two calibrations to determine the fluorescent dye and water requirement to be placed in the tank to complete the spraying operation. The dye requirement was based on the single nozzle output rate whilst the water requirement was based on the twin nozzle rate.

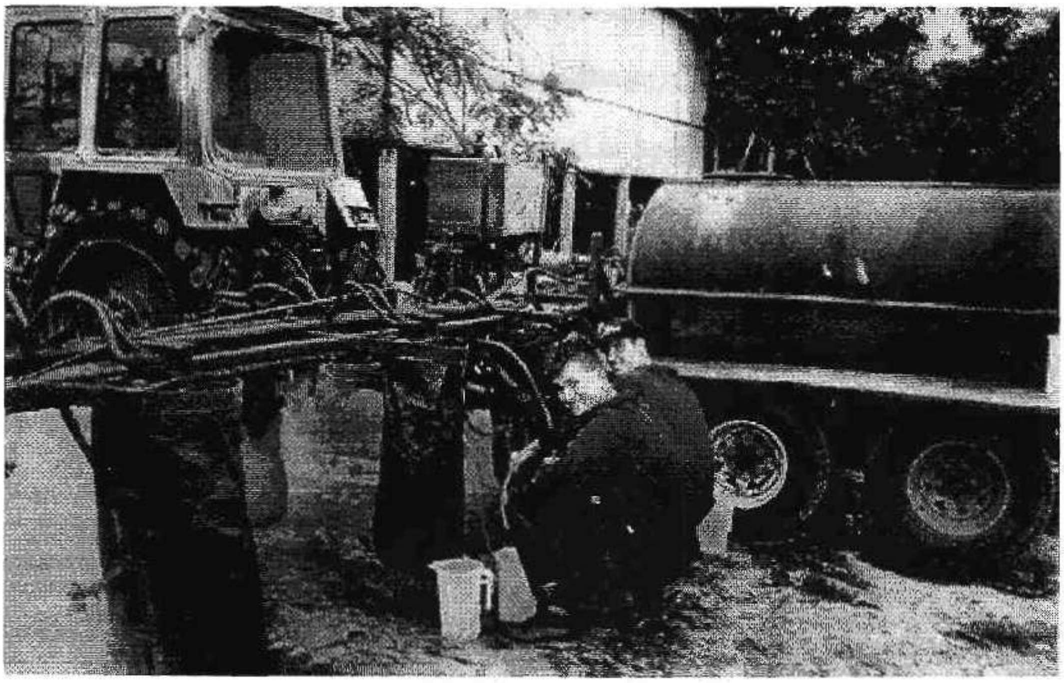

Figure 1 : Calibration of the spray rig.

Forty six milliliters of Helios SC 500 fluorescent dye and 72 mL of Agral was added to the spray tank containing 630L of water. Ground sticks were placed in each plot (1 per plot) to measure inter-row contamination. Tank samples were collected immediately prior to the spray operation, and at each block to determine ultra violet degradation of the dye. The treatments were then applied.

Sampling consisted of leaves from three plants per plot being collected, each plant being divided into four sections. These sections were:

1. Upper outer- consisting of the upper half of the plant and the leaves forming the external canopy.

2. Upper inner- consisting of the upper half of the plant and the leaves beneath the external canopy.

3. Lower outer- consisting of the lower half of the plant and the leaves forming the external canopy of the plant.

4. Lower inner- consisting of the lower half of the plant and the leaves beneath the external canopy.

Five leaves were picked from each of the designated plant zones and placed into a labeled paper bag for storage until processing. The ground sticks were collected and stored in black garbage bags to prevent photo degradation of the Helios® dye.

The samples were returned to the laboratory where the leaf area of each leaf sample was determined using an electronic planimeter. Immediately after measuring the cumulative leaf area of the five leaves the leaf samples were placed into freezer bags for fluorometric analysis.

Sixty milliliters of ethyl digol solvent was added to each of the leaf samples, and the sample shaken 50 times to rinse the dye was from the leaves. The sample rinsate was then decanted through filter paper, into a test tube and the amount of dye present determined using a fluorometer. The fluorometer was calibrated using a standard containing 400 ug of dye per litre of solution. Data was recorded as the number of micro grams of dye per litre of solution. This was then converted to the number of micro litres per centimetre squared of leaf area.

A similar procedure was followed for the second trial, the notable differences being:

1. Due to the late planting of the trial area the plants were of insufficient size to be divided into four zones. The plants were divided into two zones, upper outer and lower outer.

2. The foliage of the mulch was sampled to provide a more accurate indication of the contamination in the inter-row area. Twenty clover leaves were randomly selected from two quadrats per plot. These were rinsed with 90mls of ethyl digol before flurometric readings were taken.

An additional assessment was also made of the capsicum plants growing in the mulched areas to determine competitive effects from the mulches. From a visual assessment of the different mulch treatments it appeared that the capsicum plants in the rye grass treatments were smaller than those in any of the other treatments. To identify this apparent trend two randomly selected whole capsicum plants were removed from each plot. These were dried for a period of 72 hours in a drying oven set at 65°C. The dry weight of the plants was recorded to determine differences between treatments. Weather data for the site was recorded during the trials.

An analysis of variance was performed to statistically analysis the data using Minitab release 10,2 statistical software. Fisher's least significant difference test was applied where results were significant to determine which of the treatments applied were different.

2.5 Further Assessment of Strategic Capsicum Sprayer

After critical analysis of the initial trial results another trial was conducted to examine sprayer modifications directed at more accurate pesticide placement in the crop and minimising inter-row contamination. A number of alterations were made to Donella Farms strategic capsicum sprayer in an effort to minimise inter-row contamination and improve droplet capture in the crop. The modifications made to the sprayer included:-

- Replacing all existing nozzles with hollow cone ceramic nozzles which were operated at a pressure of 5-bar to provide a droplet spectrum with a VMD of 80-100μm.

- Installing nylon swivel type elbows to the bottom of each dropper to allow proper orientation of this nozzle.

- Adjusting each bottom nozzle so the base of the fan was angled horizontally to minimise inter-row exposure.

Nozzle angles were a major aspect considered in an effort to reduce inter-row contamination and to improve crop canopy droplet capture efficiencies. This involved connecting the nozzle to a swivel and angling it in such a fashion so that the bottom of the nozzle fan was horizontally aligned with the crop canopy base. Figure 2 demonstrates the objectives of changing nozzles angles.

Three treatments were applied using the new sprayer configuration. These were:-

- A double nozzle configuration without air assistance.
- A single nozzle configuration without air assistance.
- A single nozzle configuration with air assistance.

The sprayer was calibrated with the new nozzles and then used to apply the Helios dye solution to the field in the usual manner. A large number of leaves were sampled from the inter-row living mulches together with four crop canopy areas which were upper outer, upper inner, lower outer and lower inner sections.

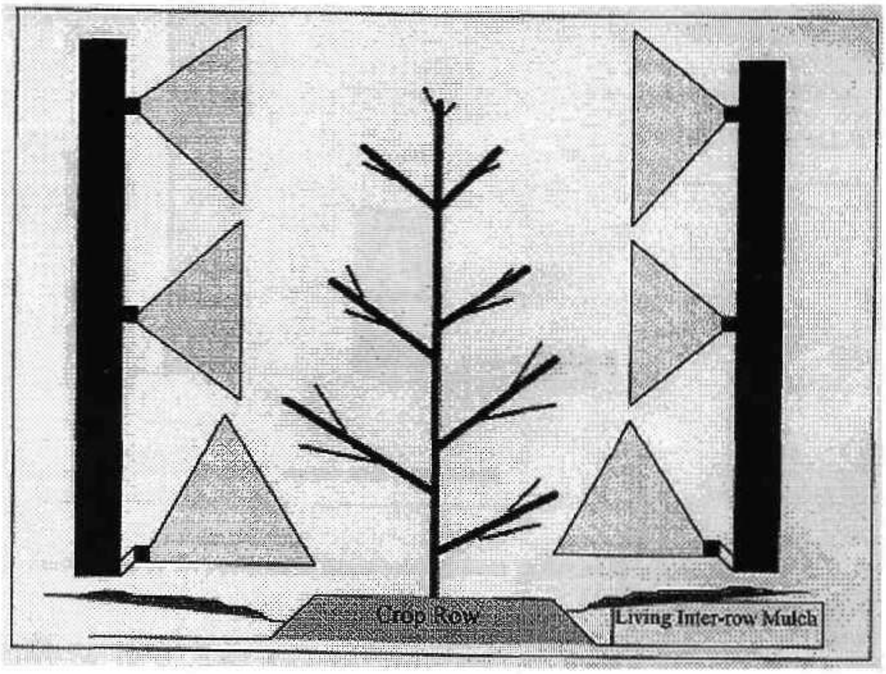

Figure 2: A diagram representing the use of nozzle angles to minimise inter-row contamination which in this case is a living mulch.

2.6 Integration of living and organic mulches into IPM for vegetables

A series of trials have been conducted in the Bundaberg and Gatton regions with a range of plant species established to form living mulches in tomato and capsicum crops. These species include rye grass (*Lolium* spp.), peanuts (*Arachius* sp), white clover (*Trifolium repens* L.), natural weedy complexes and Wynns cassia (*Chamaecrista rotundifolia*(L.f.)).

These living mulches have been trialed in conjunction with strategic pesticide application to maximise the influence of beneficial organisms. The mulches were grown from seed sown in the inter-row and headland areas prior to the establishment of each crop. Mulches where watered with over head irrigation till well established and then left to survive on rainfall and excess seepage from the trickle irrigation as the crop grew.

2.7 Impact of inter-row-mulches on pest and beneficial populations in a strategically sprayed crop. (Investigation 1)

2.7.1 Trial design

Ten plots were used for the trial each of 12 rows and each plot was 20 meters long straddling two access paths. The treatments investigated and methods of establishment of each treatment were;

Treatment 1 (WC): Wynn cassia seed broadcast with *Trichogramma* dispenser, 7 days after capsicum seedlings established at 4 Kg/ha sowing rate and lightly harrowed in,

Treatment 2 (MI): Millet seed broadcast with trichogramma dispenser 7 days after capsicum seedlings established at 10 Kg/ha and lightly harrowed in.

Treatment 3 (WE): Weeds were allowed to establish in the field from the seed bank already present in the inter-row area.

Treatment 4 (BE): Represents standard industry practice for capsicum, Roundup was used to maintain the bare earth treatment, sprayed as required (floodjet at 1 bar).

Treatment 5 (BS): Barley *(Hordeum vulgare)* straw was spread onto inter-row spaces 2 days prior to planting of seedlings to a depth of 10 cm. A further light application was made one week later after the initial straw had settled down

The treatments were randomly assigned to two adjoining blocks of five plots, with plots running down the rows forming a randomised complete block design.

2.7. 2 Choice of mulch material and species and Treatment Establishment

The living mulch treatments were a dicot monocot, and mixed species, being treatments 1-3 respectively. All living mulches were expected to flower, providing a food source for beneficial . Treatment 4 (BE), of bare earth inter-rows, represents the standard practice in vegetable production (Figure 3). Treatment 5 (BS) was originally planned as sugar cane trash. Sugar cane is grown extensively in the area and the robust nature of this trash makes it less likely to break down easily. Quite unexpectedly sugar cane trash was not available when required and barley straw was substituted in its place.

Figure 3: **Capsicum crop with bare earth inter-rows, representing standard practice, as used in treatment 4 (BE).**

Irrigation to the crop was supplied via a trickle tube laid under the plastic planting mulch, and an early overhead irrigation was also used to aid establishment of the living mulches. The live mulch treatments were mowed with a push mower twice, to prevent plants becoming too large and interfering with production practices.

2.7.3 Monitoring and spraying

Pest and beneficial species of arthropods were monitored in the main crop twice weekly, with chemical and biological control treatment recommendations based upon economic thresholds established by Crop Tech Laboratories, Bundaberg. Pesticides were applied using the growers air assisted hydraulic sprayer (Figure 4). The use of an air assisted sprayer was important to the investigation as it allowed pesticide sprays to be more accurately targeted to the crop. Mulched areas therefore received less spray from pesticide treatments than might otherwise have been the case. This method of application helped preserve beneficial insects in the mulch area that might be affected by the pesticides used in normal production activities.

Figure 4: Air assisted hydraulic sprayer used for pesticide treatments during investigation.

2.7.4 Sampling and Analysis

Major sampling for insects in each plot was undertaken on three occasions, 62 days (first assessment), 91 days (second assessment), and 127 days (third assessment) after planting of the capsicum seedlings. Two sampling systems were used including whole crop plants and the inter-row mulch area. For the whole crop plants, five plants were chosen at random to include the plant itself and the area surrounding the base of the stem for a few centimetres under the plastic mulch. The plant basal area is a popular sheltering spot for many insects associated with the plant and therefore was included in the sampling. The inter-row mulch area was sampled using five 0.33 m^2 quadrats randomly placed in the mulch area.

Sampled plants/areas for each treatment were randomly chosen from the central portion of each plot (rows 5-8) to reduce edge effects. Insects frequently move about the crop area during the day but are fairly inactive in the relative cool of early morning. Each replication required 25 whole plants to be sampled and a system for assessment was required. Sampling was spread over two consecutive mornings, one for each replication due to the time required for assessment to reduce the variation caused by the sampling time, all plants for each replication were cut consecutively and placed into a insect proof bag for thorough assessment at a later time. Samples for a complete replication could be collected in under an hour and assessed later in the research area using large magnifiers to assist identification. Mulch sampling was also performed in the mornings. This whole assessment was made in the field using a high sided quadrat to prevent insect escape. Plant disease assessments were made in the field using 10 m. rows for each treatment.

An additional assessment of the mulched areas was made during the trial to determine the dry weight of material present, the moisture status of the underlying soil, and composition of mulches. However, complete records were not able to be made for these parameters. Weather data, including relative humidity temperature, and rainfall were recorded at the trial site.

However, malfunction of the recording unit made this data unusable. Similar data was obtained for Bundaberg airport approximately five kilometres from the trial site.

Statistical analysis of results was undertaken using Minitab® release 10.2, statistical software package (Minitab Inc. 1995). The analysis of variance (anova) technique was used as appropriate, with Fisher's least significant difference (lds) test applied where results were significant All data was analysed using a (log10 y+l) transformation to give a normal distribution.

2.8 Impact of inter-row-mulches on pest and beneficial populations in a strategically sprayed crop. (Investigation 2)

From the encouraging results of the first trial (Section 3.5.1) a second investigation was undertaken to further investigate mulch influences on pest to beneficial ratios and look at different species to be used as mulches when combined with the use of the refined strategic sprayer previously developed.

2.8.1 Trial Design

The trial was a 4 x 4 randomised complete block (RCB) design with four replicates of four treatments. These treatments were :

Treatment 1 - White clover WhC *(Trifolium repens),* a living mulch
Treatment 2 - Wynn cassia WC) (*Chamaecrista rotundifolia),* a living mulch
Treatment 3 - Wynn cassia+ Rye grass (*Lolium* sp.) (WhC+RG), living mulches
Treatment 4 - Bare earth (BE) - standard industry practice, maintained by spraying herbicides.

Each block consisted of four plots running down the rows, having six rows to a plot (each plot had 5 inter-rows and an access path. The length of rows in each plot was 100m, with treatments applied randomly to each plot.

2.8.2 Selection of Mulch Material and Species and Treatment Establishment

The living mulch treatments being investigated consisted of 2 dicot species, white clover (WhC) and wynn cassia (WC) being treatments 1 and 2 respectively, and one mixed species of monocot and dicot, wynn cassia (WC) and rye grass (RG) being treatment 3. The two dicot species were expected to flower, providing a food source for beneficial insects. Treatment 4, bare earth (BE) inter-rows represented the standard industry practice in capsicum production

The selection of mulch species was made generally according to their suitability for growth in this particular region in terms of soil and climatic conditions.

The mulch treatments were applied on the 7th of June 1996, to the inter-row spaces not covered by the plastic mulch (5 inter-rows / plot), the access paths (one/plot) and also the headlands (vacant area around the edge plots). The total treated area for each plot was approximately 700m^2. Treatments 1 to 3 were broadcast with a lawn seeder at the following rates:

Treatment 1 (WhC): 2 kg/ha
Treatment 2 (WC): 8 kg/ha
Treatment 3 (WC + RG) 8 kg/ha and 4 kg/ha respectively
Treatment 4 (BE) was maintained regularly using Glyphosate® at the rate of 6 L/ha.

2.8.3 Monitoring and Spraying

Pest and beneficial species of insects were monitored in the main crop twice weekly, with chemical and biological control treatment recommendations based upon thresholds established by Crop Tech Laboratories in Bundaberg. Pesticides were applied using the strategic air assisted hydraulic sprayer which was very important for the purpose of this investigation as it allowed the chemicals to be better targeted to the crop with minimal contamination of the living mulch treatments in the inter-rows. Otherwise, chemical deposits on the mulches would affect the pest and beneficial populations in the treated areas.

2.8.4 Sampling and Analysis

Sampling for insects and plant diseases in each plot was undertaken on three occasions, 15 days (1 st assessment), 30 days (2nd assessment) and 47 days (3rd assessment) after planting of the capsicum seedlings. Two major sampling methods used were whole crop plants and the mulch areas.

For the whole crop plant samplings, 5 plants were chosen at random from each plot. Each plant was covered by an insect proof bag made from muslin gauze (to prevent insects escaping) and the plants cut at the base. These bags were then closed, labeled and taken to the laboratory for identification of the insects at a later time under a microscope and a magnifier. Two pitfall traps, containers half filled with water and a washing detergent, were also randomly laid under the plastic in the crop rows to collect any ground insects living around the crop base. These pitfalls were left in the field for three days and then collected, lids put on, labeled and then taken to the laboratory for identification of the insects at a later time.

For the mulch areas, five samples were taken from each plot using a $0.33m^2$ high sided quadrat by randomly placing the quadrat in the mulch area and counting all insects present within the quadrat. Two pitfalls were also laid randomly in the mulch areas of each plot again to catch the ground insects. Five sticky traps were also placed randomly in the mulch area of each plot to catch the flying insects. These were also left in the field for three days, then collected, labeled and covered with glad wrap and taken to the laboratory for identification. Sweepnets were also used to catch insects in each of the treatments. Insects caught in these were put in labelled jars and taken to the laboratory for identification.

Sampled plants/areas for each treatment were randomly chosen from the central portion of each plot, (rows 2-4 including the access path), to reduce edge effects. Each replication required 25 plants and 25 quadrats to be sampled and a system of assessment was required to eliminate bias in the sampling over time. Therefore sampling was spread over two consecutive mornings, two replications per morning. Samples for each treatment could be taken within an hour. Plant disease assessments were made in the field using 10m rows for each treatment as the assessment area.

An additional assessment of the mulch areas was made during the course of the trial to determine the dry weight of material present and also the moisture status of the soil for each of the treatments. Weather data, including relative humidity, temperature and rainfall were obtained from the Bureau of Sugar Experimental Stations (BSES), approximately 7km north east of the trial site.

Statistical analysis of the results was carried out by using Statistical Analysis Systems (SAS) software package. The analysis of variance (ANOVA) technique was used to identify the significance between the trials.

3.0 RESULTS

3.1 Strategic Application in tomatoes

Very little difference was recorded between the pitfall and sticky traps for the different treatments, although at the first sampling, the lowest arthropod population in the sticky traps was in the complete chemical cocktail treatment, and the highest numbers in the pitfalls was the Bt only treatment. However, due to high overall variability, .population assessment was based mainly on the destructive samples. No nematodes were found on the sampled plants. Total arthropod numbers were higher on the "softer" (Bt only; Bt+Larvin) than the "heavier" (chemical cocktail top and complete) treatments (refer to Figure 5). Mite populations were not included as they were partially estimated due to extremely high numbers.

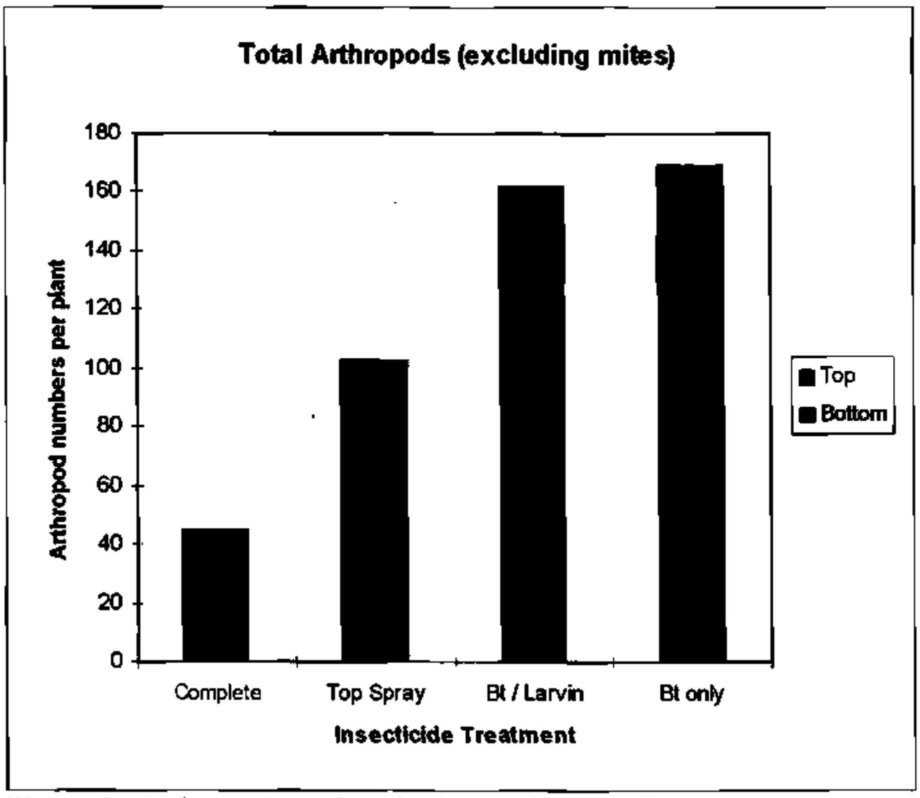

Figure 5: Arthropod numbers in destructive sampling

Helicoverpa counts showed a high level of larvae in the Bt only treatment at the time of the first destructive sampling (Table 4). This was reflected in a high level of fruit damage in this treatment at harvest. The complete cocktail treatment initially showed high egg counts, but low larval levels by the second destructive sampling. The highest level of parasitised *Helicoverpa* eggs was recorded in the Bt only treatment during the second destructive sampling (Table 5).

Table 4: Destructive sample 1 - Helicoverpa (average per plant)

	Bt Only	Bt/Larvin	Top Spray	Complete
Heliothis Eggs - Bottom	0.33	0	0	0
Heliothis Eggs - Top	4	5.5	5	8.5
Heliothis Larvae - Bottom	2	0.67	1	0.33
Heliothis Larvae - Top	5.67	2.67	1.5	2.33

Table 5: Destructive Sample 2 - *Heliothis* whole plant

	Bt Only	Bt/Larvin	Top Spray	Complete
Heliothis Eggs	8	8.17	6.17	2.83
Heliothis Larvae	0.67	0.33	0.16	0
Parasitised Eggs	4	0.5	0.67	0.17

Aphid numbers were highest in the lower plant canopy. High aphid parasitism was recorded in the Bt only and Bt/Larvin treatments during the second destructive sampling (Table 6). Overall, aphid numbers appeared to mirror total arthropod numbers, with the lowest populations in the complete cocktail treatment.

Table 6: Aphids (average per plant)

	Bt Only	Bt/Larvin	Top Spray	Complete
Destructive 1	26.67	49.16	397.83	54.5
Destructive 2	10.28	8.64	6.08	3.97
Parasitized aphids (D2)	18	37.83	10	1.67

Two-spotted mite populations were very high in all treatments, with the highest levels in the top third of the bush. Lacewing, potato tuber moth and disease levels were all consistently low within treatments (table 7). Viral disease levels were slightly higher in the Bt only treatment, possibly due to a slightly higher incidence of sucking insects in this treatment. (Table 8)

Table7: Other Arthropods per bush (Destructive 2 unless otherwise stated)

	Bt Only	Bt/Larvin	Top Spray	Complete
2-spot Mites - D1	3.83	0.67	4	53.25
2-spot Mites - D2	947.5	785	1060.83	696.67
Lacewings	2.5	2.83	5	3.5
Potato Tuber Moth Larvae	1.83	9.83	3.33	1

Table 8: Number of plants showing symptoms of purpletop recorded in disease transects.

	Bt Only	Bt/Larvin	Top Spray	Complete
18 November	4	0	0	1
21 November	4	1	2	4
2 December	6	2	2	5

Fruit numbers and yield remained relatively constant between treatments. High losses due to *Helicoverpa* were recorded during the second destructive and strip-pick sampling in both the Bt only and top-spray cocktail treatments. This was particularly noticeable in the Bt only treatment, where the high proportion rotten fruit initiated complaints from pickers. (Tables 6-9)

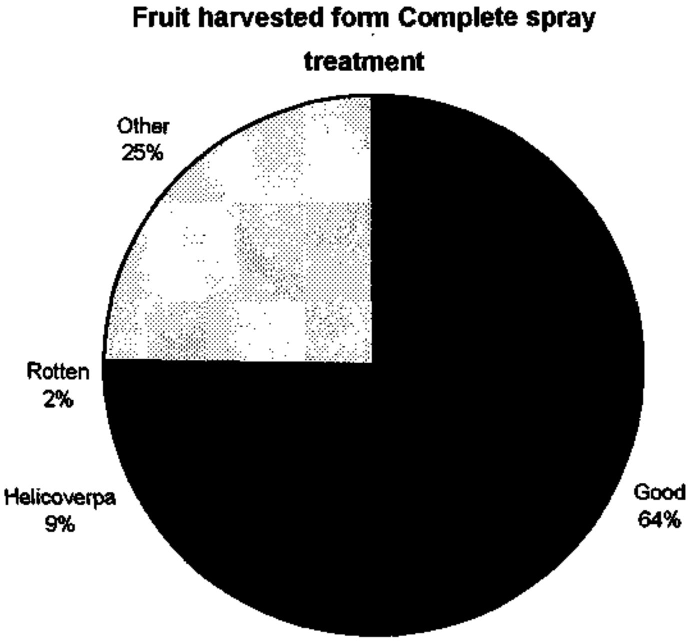

Figure 6 Fruit harvested from Complete Spray Treatment

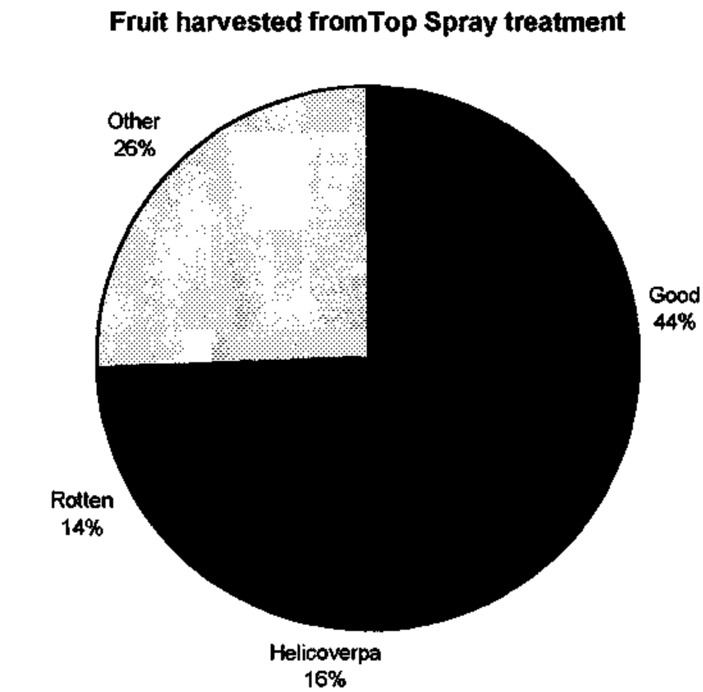

Figure 7 Fruit harvested from Cocktail Top Spray Treatment

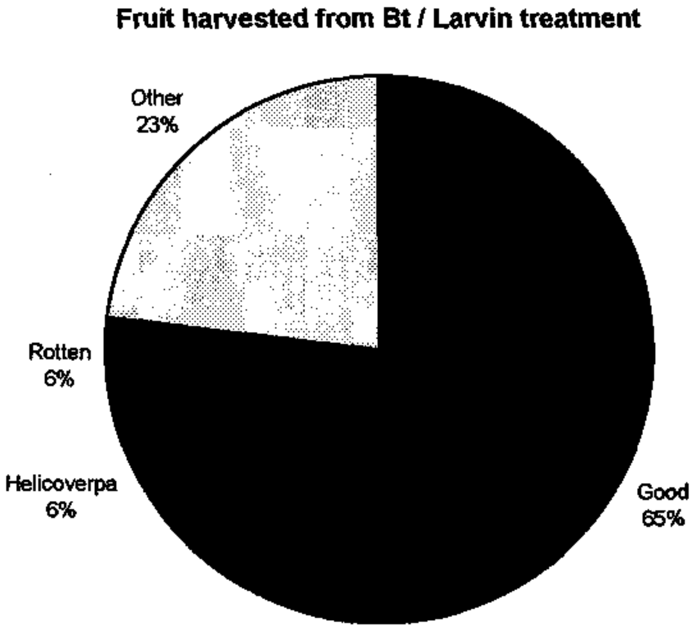

Figure 8: Fruit harvested from Bt / Larvin Top Spray Treatment

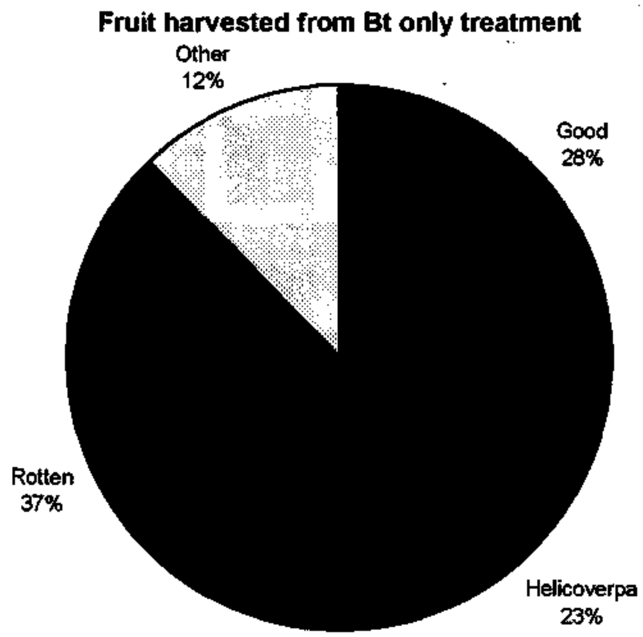

Figure 9: Fruit harvested from Bt only treatment

The assessment of marketable yield is the most important definitive rating of the success of a pest management strategy. This trial indicated that in terms of final yield, strategic spraying could be a viable alternative to conventional whole plant canopy spraying with the yields of marketable fruit with these two treatments being comparable. Further work was therefore carried out to investigate the effects of carefully selecting the pesticides used in a strategic spraying program.

3.2 Integration of Biological Controls into Tomato Production

Pre-release samples in Block 3 showed very low levels of parasitism (3.9%) from local *Trichogramma* wasps, mainly *T. australicum.* and only 1. 1 % in the control, Block 7. After the first release on 22 Aug, sentinel cards were placed in the crop on 23 Aug and collected on 26 Aug. Parasitism levels rose to 60.1% over Block 3. 92% of this was the result of the released species *Trichogramma nr brassicae.*

An anomaly occurred in one plot, the Trich+Bt plot, on 30 Aug: Parasitism in this plot dropped to 6.4% while most other plots had an increase on the previous week. This pulled down the overall parasitism for Block 3. Reasons for this drop were investigated but no clear cause has been identified.

Otherwise, parasitism continued to rise and to a peak on 6 Sept at 84.4% over Block 3. Soon after this peak, on 12 Sept the spray trial commenced and parasitism plummeted to close to zero in all treatments from that time.

3.3 Investigations into Nozzle Technologies - wear and droplet sizes.

3.3.1 Nozzles And Pressure

Pressure was found to directly influence nozzle performance. High pressures reduced droplet size and increased flow rates in all the respective nozzle types tested. Nozzle orifice size also influenced droplet size and flow rate. A relationship exists between nozzle size and pressure as the smaller the nozzle orifice and the higher the pressure the smaller the droplets produced. Small droplets of approximately 100μm are the most effective for applying insecticides and fungicides to vegetable crops. Table 9 shows the Lurmark range of nozzles which were tested at three pressures. It can be seen that a range of different nozzle orifice and swirl plate combinations can be used provided that the appropriate pressure is used to produce the required droplet sizes. Lurmark nozzles are used in this example however nozzles from all manufacturers were found to share similar characteristics provided that appropriate pressures are selected and used. Full nozzle details are provided in Appendix

Table 9 The Lurmark range of hollow cones tested at varying pressures

Nozzle Type	Pressure (Bar)	VMD (um)	Span	Flow Rate (L/m)
Lumark D2s13	5	89	1.60	0.39
	7	78	1.54	0.45
	10	71	1.56	0.53
Lumark D2s23	5	97	1.64	0.51
	7	88	1.65	0.60
	10	88	1.73	0.70
Lumark D2s25	5	129	1.58	0.79
	7	129	1.55	0.93
	10	125	1.58	1.10
Lumark D3s23	5	105	1.49	0.58
	7	102	1.64	0.68
	10	94	1.69	0.80
Lumark D3s25	5	144	1.58	0.94
	7	140	1.56	1.13
	10	137	1.59	1.34

Lumark D3s45	5	175	1.53	1.15
	7	166	1.51	1.33
	10	154	1.58	1.60
Teejet D2s13	5	88	1.48	
	7	78	1.45	
	10			
Teejet D2s23	5	96	1.56	0.57
	7	91	1.58	0.67
	10	90	1.57	0.80
Teejet D2s25	5	120	1.57	0.81
	7	121	1.54	0.93
	10	115	1.54	1.13
Teejet D3s23	5	103	1.46	0.64
	7	97	1.53	0.77
	10	94	1.53	0.92
Teejet D3s25	5	125	1.55	0.92
	7	123	1.53	1.08
	10	120	1.52	1.27
Teejet D3s45	5	174	1.58	1.22
	7	162	1.56	1.44
	10	150	1.63	1.72
Albuz 1299-08	5	85	1.42	0.37
	7	79	1.47	0.43
	10	77	1.46	0.51
Albuz 1299-10	5	86	1.52	0.49
	7	86	1.53	0.57
	10	82	1.57	0.68
Albuz 1299-12	5	102	1.54	0.77
	7	100	1.60	0.90
	10	100	1.60	1.07
Albuz 1299-14	5	111	1.54	0.95
	7	109	1.60	1.12
	10	107	1.63	1.31
Albuz 1299-46	5	141	1.63	1.40
	7	141	1.62	1.64
	10	133	1.70	1.95
Spray Sys TX 3C	5	65	1.26	
	7	67	1.29	
	10	63	1.29	
Spray Sys TX 4C	5	72	1.36	
	7	72	1.35	
	10	68	1.35	
Spray Sys TX 3C	5	79	1.47	
	7	83	1.48	
	10	80	1.52	
Spray Sys TX 6C	5	94	1.56	
	7	104	1.55	
	10	101	1.55	

Spray Sys TX 10C	5	66	1.21
	7	66	1.41
	10	58	0.98
Spray Sys TX 2B	5	70	1.30
	7	69	1.17
	10	57	1.26
Spray Sys TX 4B	5	75	1.46
	7	76	1.34
	10	61	1.52
Spray Sys TX 6B	5	86	1.48
	7	81	1.40
	10	74	1.60
Spray Sys TX 10B	5	103	1.57
	7	101	1.53
	10	91	1.72
Spray Sys TX 12B	5	117	1.62
	7	112	1.56
	10	105	1.73

3.4 Impact of strategic pesticide use on the pest/beneficial ratios in inter-row plantings - Capsicum

3.4.1 Spray Trial 1 Results

The mean amount of dye recovered from the sampled capsicum plants for each treatment in the first spray investigation is illustrated in table 10. The mean quantity of dye recovered for each treatment in each block follows a similar trend with the exception of block 2.

Table 10. Mean dye recovery for four positions in the mature capsicum canopy.

Block	Treat	height	canopy	Recovery (uL/cm^2)	Block	Treat	height	canopy	Recovery (uL/cm^2)
1	1	upper	outer	4.534	3	1	upper	outer	4.382
1	1	upper	inner	2.976	3	1	upper	inner	2.342
1	1	lower	outer	3.523	3	1	lower	outer	2.250
1	1	lower	inner	1.838	3	1	lower	inner	1.471
1	2	upper	outer	5.336	3	2	upper	outer	6.720
1	2	upper	inner	2.84	3	2	upper	inner	3.372
1	2	lower	outer	3.144	3	2	lower	outer	2.339
1	2	lower	inner	1.715	3	2	lower	inner	0.637
1	3	upper	outer	3.545	3	3	upper	outer	4.013
1	3	upper	inner	1.960	3	3	upper	inner	2.103
1	3	lower	outer	2.533	3	3	lower	outer	2.148
1	3	lower	inner	1.611	3	3	lower	inner	1.382
1	4	upper	outer	4.859	3	4	upper	outer	4.518
1	4	upper	inner	1.421	3	4	upper	inner	1.553
1	4	lower	outer	2.095	3	4	lower	outer	1.867
1	4	lower	inner	0.929	3	4	lower	inner	0.842
2	1	upper	outer	4.243	4	1	upper	outer	5.297
2	1	upper	inner	2.120	4	1	upper	inner	1.981
2	1	lower	outer	2.281	4	1	lower	outer	3.635
2	1	lower	inner	1.789	4	1	lower	inner	1.858
2	2	upper	outer	3.169	4	2	upper	outer	5.948
2	2	upper	inner	1.470	4	2	upper	inner	3.488
2	2	lower	outer	1.688	4	2	lower	outer	3.049
2	2	lower	inner	1.162	4	2	lower	inner	1.394
2	3	upper	outer	3.490	4	3	upper	outer	3.784
2	3	upper	inner	1.776	4	3	upper	inner	2.538
2	3	lower	outer	1.660	4	3	lower	outer	1.974
2	3	lower	inner	1.173	4	3	lower	inner	0.888
2	4	upper	outer	3.304	4	4	upper	outer	3.486
2	4	upper	inner	2.856	4	4	upper	inner	1.414
2	4	lower	outer	1.99	4	4	lower	outer	2.330
2	4	lower	inner	1.129	4	4	lower	inner	0.848

From the data presented in table 10 it can be seen that a number of trends are evident. There appear to be differences between the treatments, with the amount of dye recovered from the inner and outer canopies and at the two heights which were different. An analysis of variance was conducted on these results to determine if the apparent differences were significant. The significant results are listed in table 11.

Table 11 Results from analysis of spray treatments applied

Source	D17	SS	MS	F	P
Block	3	3.4633	1.1544	3.29	0.029
Treatment	3	7.5746	2.5249	7.20	0.000
Height	1	35.4079	35.4079	101.02	0.000
Canopy	1	42.7586	42.7586	121.99	0.000
Height x Canopy	1	4.3292	4.3292	12.35	0.001

The data and analysis in table 4 shows that highly significant differences were evident between treatments, heights of application, canopy and there also was a highly significant height x canopy interaction. There was also a significant difference between blocks. To determine which of the treatments were significant the data was analysed using Fisher's Lsd test. The results of this test are shown in table 12.

Table. 12 Overall means and Lsd's for the significant results obtained.

Source	means (UL/CM2)	Lsd	rating
Block 1	2.8037		a
Block 2	2.2064		b
Block 3	2.6213		ab
Block 4	2.7406	0.4230	a
height (upper)	3.3368		a
height (lower)	1.8492	0.299	b
Canopy (outer)	3.4104		a
Canopy (inner)	1.7746	0.299	b
Treatment 1	2.9037		a
Treatment 2	2.9671		a
Treatment 3	2.2863		b
Treatment 4	2.2149	0.4230	b
Upper*outer	4.4143		a
Upper*inner	2.2594		b
Lower*outer	2.4065		b
Lower*inner	1.2919	0.4230	c

This data shows that treatments 1&2 (twin nozzles) are significantly different from treatments 3&4 (single nozzles). There is however, no significant difference between treatments 1&2 with treatment 1 including air assistance. The result was the same for treatments 3 and 4. Block 2 was significantly different from blocks 1,3, and 4 while the exact nature of the difference is unknown it may have been due to the wind conditions experienced at the time of application.

The amount of dye recovered on the outside of the capsicum plant canopy was significantly higher than that recorded on the inner plant canopy for all treatments. There was a greater recovery of dye on the top of the plants when compared to that recovered on the lower half of the plants. Figure 10 shows the level of dye recovered for all treatments and blocks as well as the amount of dye recovered on the whole plant for each treatment.

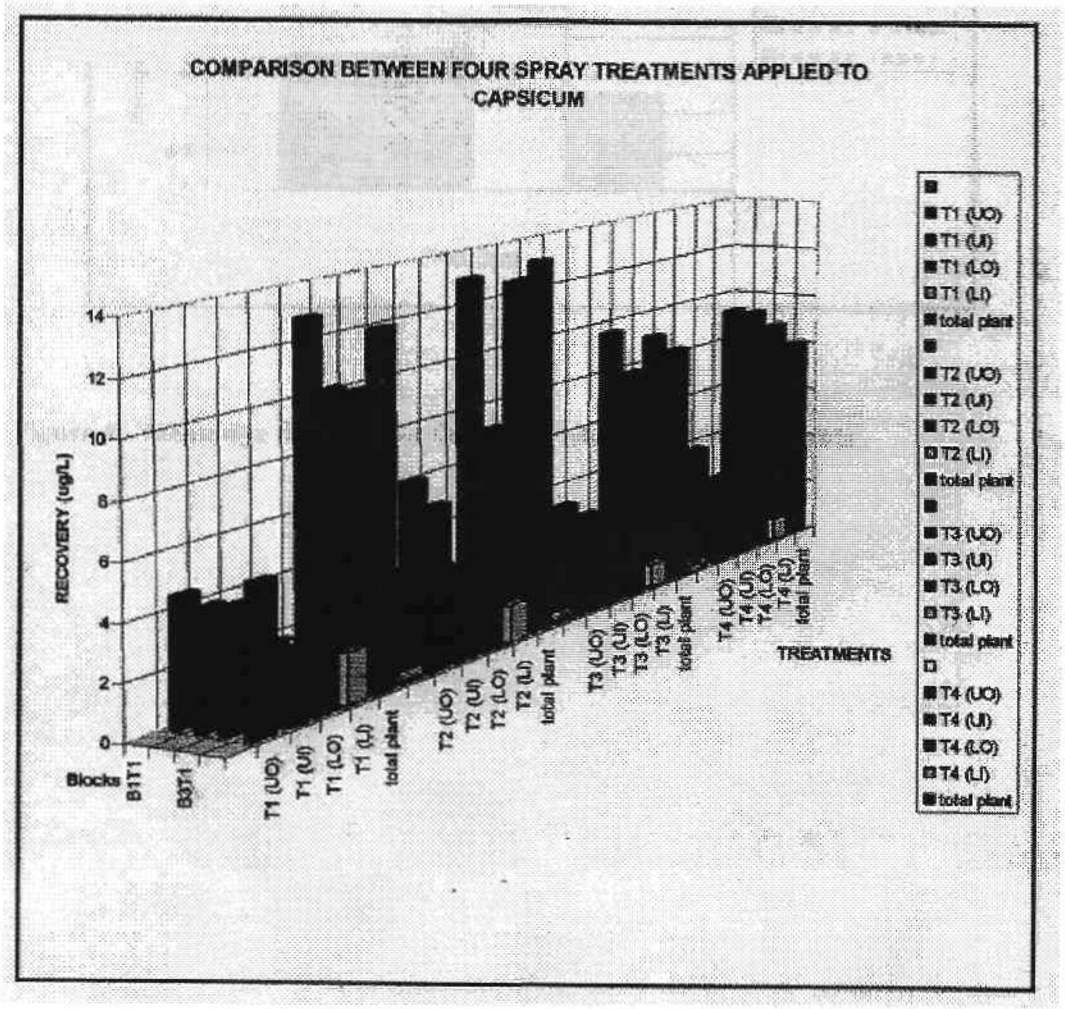

Figure 10: Comparison of Deposits on Capsicum Canopies for the Four Spray Treatments.

The height by canopy interaction is shown in figure 11 which shows for all treatments the mean quantities of dye recovered at the respective positions on the capsicum plants.

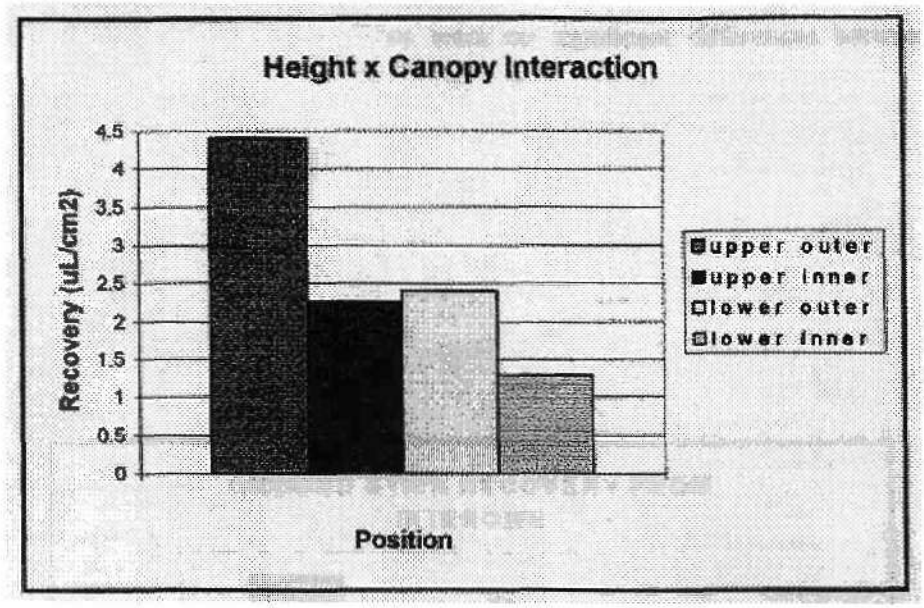

Figure 11: Mean dye deposits for four positions in capsicum plants.

The level of contamination of the inter-row spaces was measured. This data is shown in figure 12. This shows that a trend exists in treatments 2 and 4. These treatments did not include air assistance to increase spray penetration into the capsicum plants with the result that there is less contamination of the inter-row. A statistical analysis of the deposit data showed that there were no significant differences between the treatments applied.

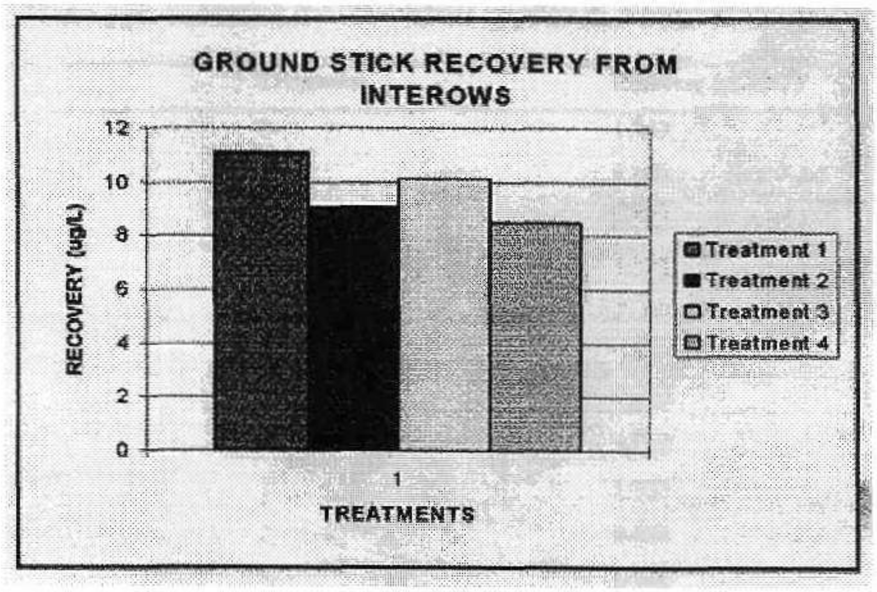

Figure 12: Dye recovery from inter-row ground sticks for each treatment.

3.4.2 Spray Trial 2 Results.

The second investigation was conducted in the mulched trial area and a more accurate representation of the contamination levels occurring within the mulches obtained. Capsicum plants sprayed in the trial area were only half grown due to the late planting date caused by loss through flooding of the first trial planting, this influenced the amount of dye collected, and the differences between treatments.. The mean quantities of dye recovered in the white clover mulch for each of the treatments applied is set out in table 13.

Table 13. Mean dye recoveries for treatments applied in white clover mulch.

Block	Treatment	Recovery (uLlcm2)
1	1	1.253
1	2	1.259
1	3	1.532
1	4	1.975
2	1	2.360
2	2	0.841
2	3	1.438
2	4	1.730
3	1	1.553
3	2	0.644
3	3	1.140
3	4	1.014
4	1	2.187
4	2	1.705
4	3	1.483
4	4	1.156

The analysis of variance performed on the data showed that there were no significant differences between the treatments applied. It can be seen from the data in figure 13 however, that the amount of dye recovered from treatment 1 although not significant is higher than the other applied treatments with a p value of 0. 157 . The lowest recovery is in treatment 3 (single nozzles with air) which contradicts the findings recorded in first spray trial and is more likely to reflect the real dye deposits associated with the particular treatments.

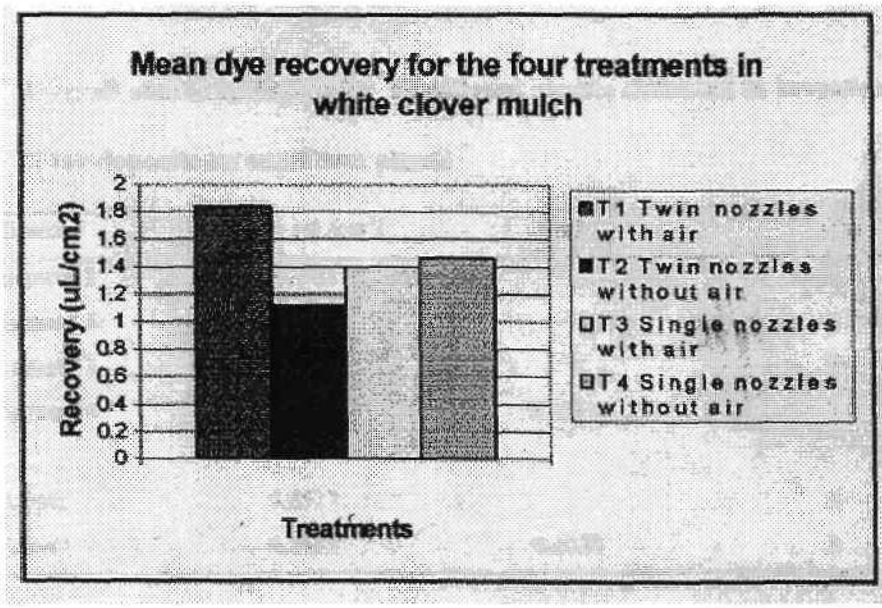

Figure 13: Mean Dye recovery of the four treatments in white clover mulch.

The levels of dye recovery from the capsicum plants sprayed in the second trial are shown in table 7. Variations in the amount of dye deposited are evident when compared to the first spray trial. However, the trends in the data are similar to those found in the first spray trial. Treatments 1 & 2 using the twin nozzles deposit a greater amount of dye on to the capsicum plants than do treatments 3 & 4 using single nozzles.

The data was analysed using an analysis of variance to determine if there were significant differences between treatments . Significant differences were detected between the treatments applied and at the two different sampling heights (upper and lower). The treatments were further analysed using Fisher's Lsd test to determine which treatments were significant table 14.

Table 14 Overall means and Lsd's for significant results obtained in investigation 2 for deposits on capsicum plants

Source	Means (uL/cm2)	Lsd	rating
Treatment 1	5.7582		a
Treatment 2	5.6178		a
Treatment 3	4.1774		b
Treatment 4	4.4382	0.59716	b
Upper	5.6527		a
Lower	4.3431	0.4222	b

This information shows that treatments 1 & 2 are significantly different from treatments 3 & 4 however, there is no significant difference between treatments 1 & 2 or 3 & 4. The deposits on the upper half of the plant are significantly different from those on the lower half of the plant with the upper half receiving a greater concentration of dye. These results have the same the trend demonstrated in the first spray trial for deposits on and in the crop.

3.4.3 Competition between the living mulch and the crop.

The weights of whole capsicum plants are compared in figure 14, to determine the extent to which the mulches are competing with the crop. The weights of the capsicum plants were analysed using the ANOVA technique which indicated that there was no significant difference between any of the mulch treatments at this particular stage of growth, plants were half grown.

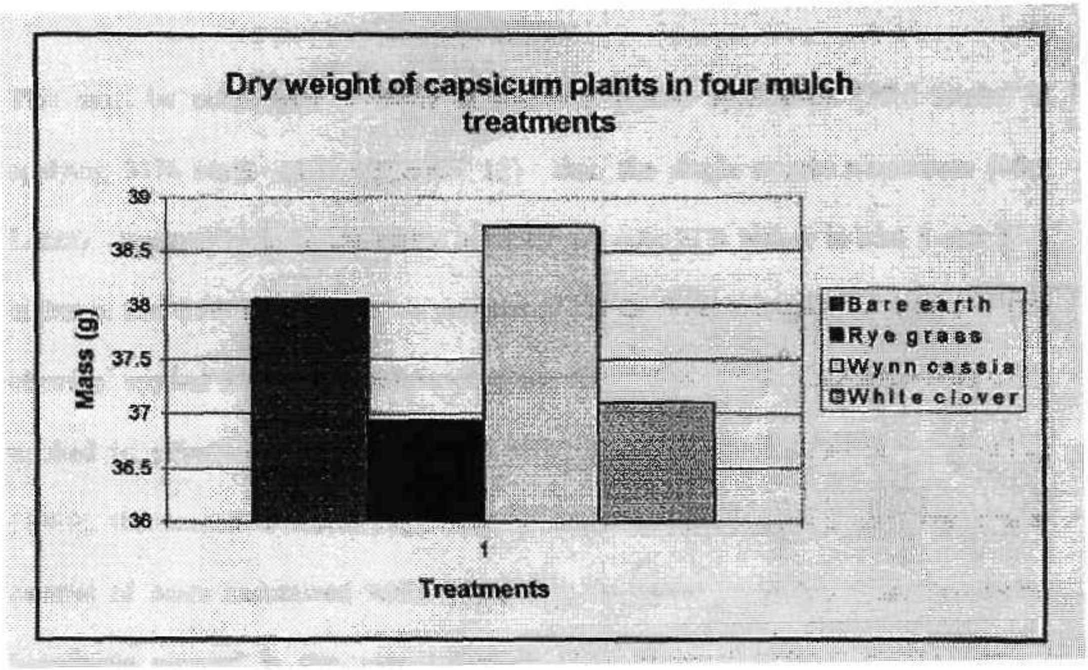

Figure 14: Dry weight means of capsicum plants for each of the mulch treatments.

The bare earth and the wynn cassia treatments had a higher dry matter yield than the rye grass or white clover. The inter-row wynn cassia treatment established very poorly and more closely resembled the bare earth treatment. The data shows that although no significant differences were detected the mulches may affect the growth of the capsicum plants particularly as the crop matures, and thus affect final yield .

The results from the second fluorometric trial provided interesting results. Inter-row mulch contamination was reduced when compared to the previous set up used in Trial 1. Double nozzles (high volume) once again gave very high inter-row contamination rates. Single nozzles without air assistance lowered contamination but the use of single nozzles with air assistance gave the lowest mulch contamination levels. These results can be seen in figure 15.

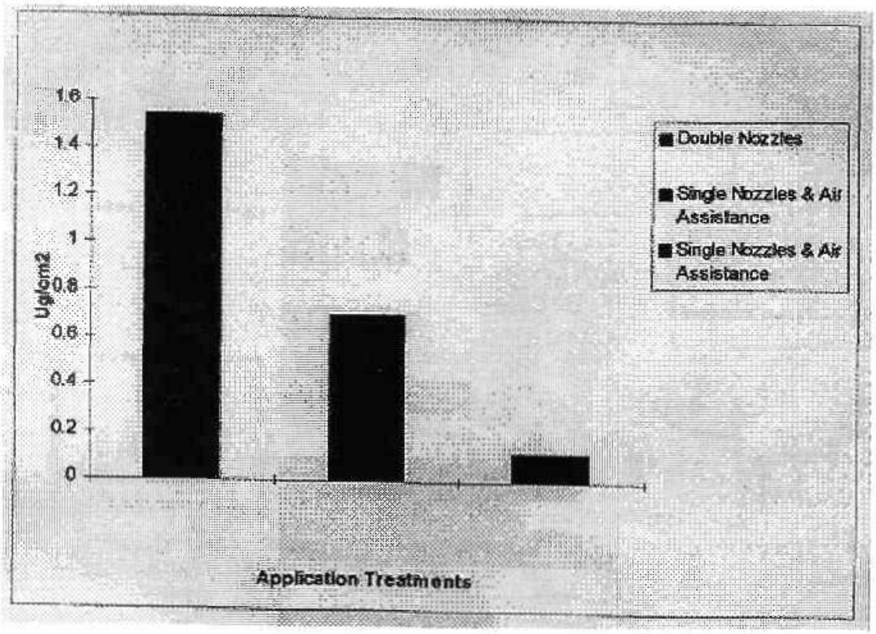

Figure 15: Dye Deposition in Inter-row White Clover Mulch Areas.

The dye capture in the canopy also yielded some interesting results. The use of double nozzles only increased the crop's capture marginally when compared to the use of single nozzles. Considering that the application volume was increased by more than 37% the canopy capture rate did not reflect this higher rate of application. The level of efficiency therefore with the higher volume of application was quite low. These losses from the crop however were partially reflected in the increased inter-row contamination levels.

The single nozzle configuration provided much greater canopy droplet capture efficiency rates which can be seen in the results shown in figure 16. The main trend which was apparent in the crop deposition results was the high levels recorded in the lower canopy areas. The increased deposition is simply the result of the increased application created by the overlap between the bottom and middle nozzle sets.

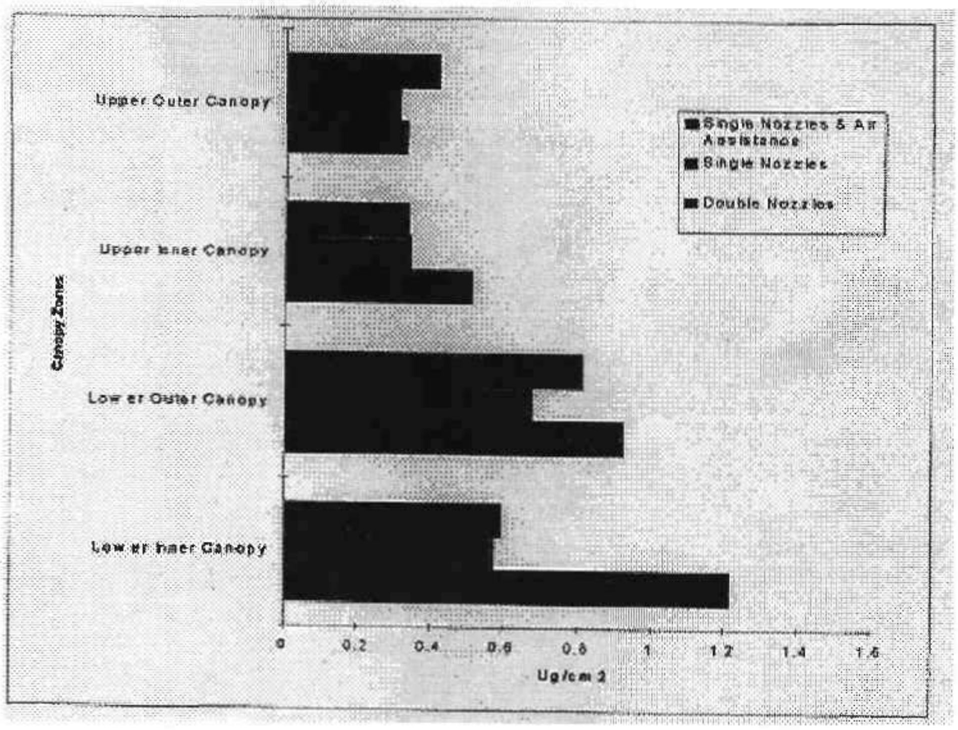

Figure 16: Dye deposition in the capsicum crop canopy.

When comparing the strategically adjusted sprayer configuration with the original configuration a number of improvements can be seen. Inter-row contamination has been decreased considerably which fulfilled the aim of the exercise. The level of reduction is shown in figure 17. This reduction is important both in terms of general environmental contamination and the presentation of beneficials in the inter-row mulch.

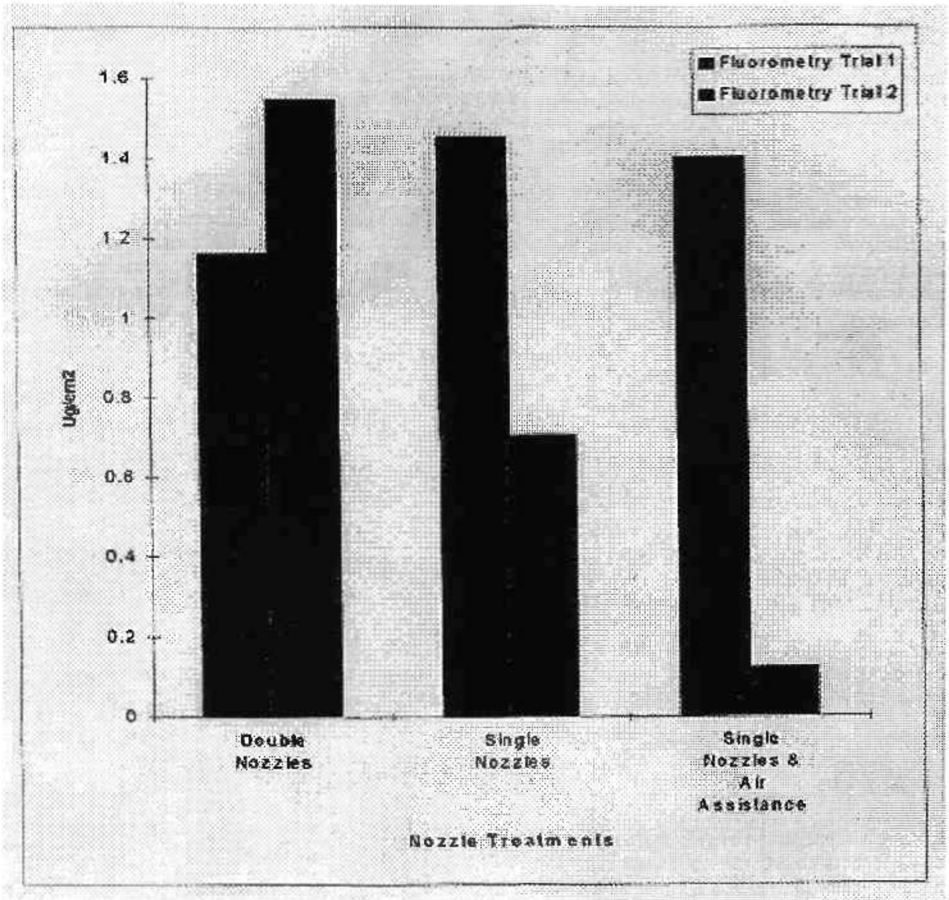

Figure 17: A comparison of mulch contamination between trial 1 and 2.

3.5 Impact of inter-row-mulches on pest and beneficial populations in a strategically sprayed crop. (Investigation 1)

3.5.1 Whole plant counts

Of all the insects monitored over the three assessments, only five insects were recorded in sufficient numbers to carry out an analysis of variance of the data. Total insect numbers doubled at each successive assessment, but the number of species observed remained relatively constant A summary of the most abundant insect counts appears in table 15, only those counts highlighted were analysed.

Table 15 Number of insects monitored in whole crop plant counts by each assessment for the most abundant species.

Insect	Number Counted			Total Number
Assessment	1	2	3	
Aphids	78*	1506*	2329*	3913
2 spotted mites	3	21	1327*	1351
Parasitised aphids	2	41	318*	389
Spiders	328*	371*	318*	1017
Predatory beetles	137*	155*	68*	360

*data for these insects/assessments were analysed using anova

Significant differences between treatments were found for aphid, spider, two-spotted mite and jassid whole plant counts using an analysis of variance. The lsd analysis to determine the significant results is presented in table 16 below. The results show that of the eleven anova comparisons made, only three were significant The block comparisons for aphids and spiders were highly significant, indicating a block effect. The block effect may have been the result of sampling on different days, although sampling was made at the same time on each day.

Table 16. Back transformed treatment mean counts and Lsd's for the significant results of crop insect plant counts.

Insect		Aphids	2 spotted mite	Spiders
Treatment No		3	3	1
Wynn cassia (1)	(WC)	17.85b	0.66c	3.79b
		(1.27)	(0.22)	(0.68)
Millet (2)	(MI)	32.11ab	4.75ab	5.31b
		(1.52)	(0.76)	(0.80)
Weeds (3)	(WE)	17.20b	4.62ab	4.01b
		(1.26)	(0.75)	(0.70)
Bare earth (4)	(BE)	74.86a	10.75a,	5.76ab
		(1.88)	(1.07)	(0.83)
Barley straw (5)	(BS)	13.79b	1.19bc	9.00a,
		(1.17)	(0.34(	(1.00)
p~value		0.04	0.02	0.04
Lsd (trans) $p< 0.05$		0.40	0.42	0.18

Untransformed means given in parentheses. Fishers lsd was calculated on the transformed scale. Treatment means have been back transformed to original scale. Lsd is untransformed (logio +1), means followed by the same letter are not significantly different p>0.5

The Lsd analysis shows that aphid counts were significantly higher in treatment 4 (BE) compared to treatments 1 (WC), 3 (WE), 5 (BS). Treatment 2 (MI) was not significantly different from any other treatment Spider counts in treatment 5 (BS) were significantly higher than treatments 1 (WC), 2 and 3 (WE). Treatment 4 (BE) was not significantly different from any other treatment The differences for mites were less clear with only treatment 4 (BE) having higher populations than treatments 1 (WC) and 5 (BS). Significant effects were only detected in assessment 3 for aphids and mites, and assessment 1 for spiders. All other treatment comparisons were not significantly different from each other. These results indicate that treatment 4 (BE) had the highest numbers of important pests and there were significant differences between this and other treatments. A comparison of insect counts by treatment for all assessments (Table 17) identifies some interesting trends. It shows that treatment 4 (BE) contained nearly twice the number of insects counted compared to any other treatment This was due largely to the high numbers of aphids and two-spotted mites in this treatment.

Table 17. Crop plant insect numbers for the total of all assessments by treatment and species - Pests and Beneficials

Treatment	T1 (WC)	T2 (MI)	T3(WE)	T4 (BE)	T5 (BS)	Total
Aphids	286	715	388	1987	537	3913
Heliothis eggs	29	30	35	46	24	164
Heliothis larvae	1	7	1	5	4	18
2 Spotted mite	27	343	311	525	145	1351
Jassids		1		1	4	6
Looper egg	2	3		2		7
Looper grub				1	1	2
Thrips	1					1
Cricket	5	4	10	4	6	29
Mealy Bug	2	11	0	7	80	100
Mealy bug eggs	4	60				64
Wireworm		2	4		3	9
Clust. c/pillar egg	90			65		155
Cluster caterpillar	1				1	2
Sub-total pests	448	1176	749	2643	805	5821
Parasitised eggs	32	48	44	50	47	221
Parasitised aphids	46	109	40	144	50	389
Predatory mites	3	15	7		2	27
Spiders	176	192	173	252	224	1017
Lacewing eggs	37	86	37	48	52	260
Lacewing	2	5	3	5	2	17
Parasitic wasp	2	2	2	3	1	10
Predatory beetle	57	72	85	76	70	360
Ladybird (pred)		1	3	1	2	7
Big eyed bug	9	8	7	7	9	40
Earwig	1	2	9	9	15	36
Pred thrip		2	2	1	2	7
Sub total beneficials	365	542	412	596	476	2411
Total	813	1718	1161	3239	1281	8212
No of species	22	23	22	22	23	

Species diversity appeared to remain constant for all assessments, but some slight variations occurred between particular assessments. A comparison of the ratio of beneficial to pest insect species was made for each assessment to identify trends between them for each treatment (Figure18). This shows that some treatments had different ratios to others. Treatment 4 (BE) particularly, had a low beneficial to pest ratio for all assessments compared to other treatments.

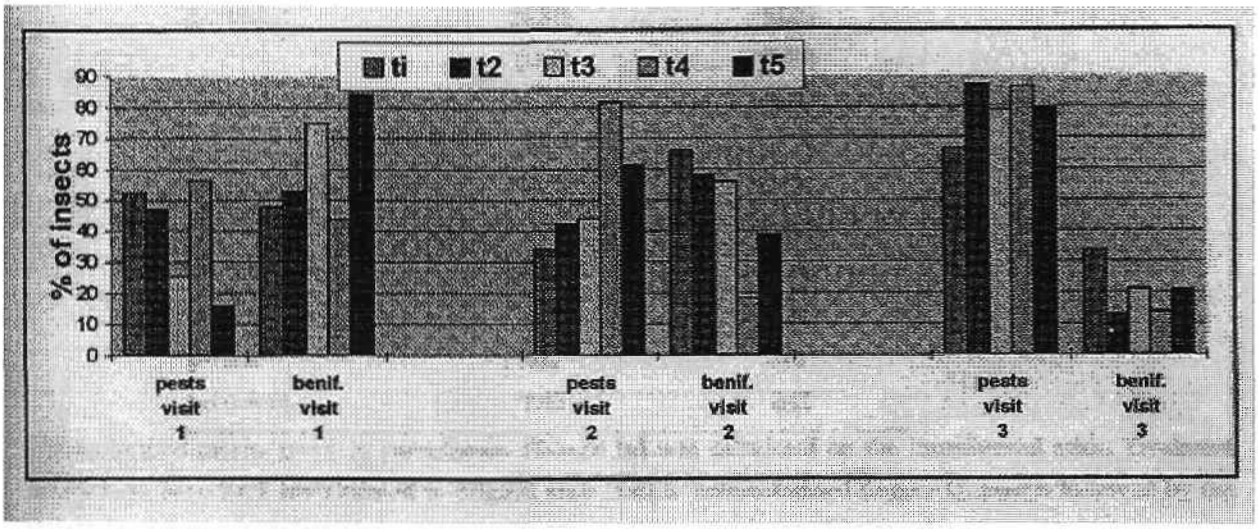

Figure 18: Percentage of beneficial and pest insects for each treatment by each assessment

A further analysis was carried out on the combined data for the most numerous insects, from all three assessments to investigate the overall trends. The was particularly interesting for aphids, as the Lds separated treatment 4 (BE) from all other treatments. This analysis also separated mites into two distinct groups with treatments 1 (WC) and 5 (BS) having lower populations of mites than any other treatment There were no significant differences between treatments for parasitised aphid, spider and predatory beetle counts. A summary of the significant effects is presented in table 18.

Table 18: Back transformed treatment mean numbers and Lsd's for significant results of combined crop plant assessment counts.

insect	Aphids	two-spotted mite
Treatment		
T 1 Wynn cassia	24-12b	0.66b
	(1.40)	(0.22)
T 2 Millet	38.81b	5.03a
	(1.60)	(0.78)
T 3 Weeds	26.54b	4.62a
	(L44)	(0.75)
T 4 Bare earth	168.82a	10.75a
	(2.23)	(1.07)
T 5 Barley straw	20.88b	1.19b
	(1.34)	(0.34)
p-value	.022*	0.02*
Lsd (trans)	0.45	0.41

Untransformed means given in parentheses. Fisher's Lds was calculated on the transformed scale. Treatment means have been back transformed to original scale. Lsd is untransformed (log10 +1), means followed by the same letter are not significantly different p>0.05,

3.5.2 Mulch area counts

Unlike the plant counts, insect counts in the mulched area did not continually rise for each successive assessment Insect counts peaked at the second assessment with similar counts on the first and third assessments. Total insect numbers were considerably lower for the mulch area counts, indicating that most insects were associated with the crop plants. An analysis of all insects species monitored by assessment time, revealed that only three insects were monitored in sufficient abundance for an individual assessment to use an' analysis of variance. The anova for the three insects, Jassids, spiders and predatory beetles, showed significant differences between treatments in jassid counts only. The Lsd for jassid treatment means showed that treatment 4 (BE) had significantly lower populations of jassids; than any other treatment (table 7). Treatment 2 (MI) contained higher populations of jassids than treatments 1 (WC), 4 (BE) and 5 (BS). Although not significant spiders had a p-value of 0.057, only just outside the significant range at the 5% level. The highest mean count for spiders was found in treatments 1 (WC) and 3 (WE).

Table 19. Back transformed treatment mean numbers and Lsd's for significant results of mulch area counts.

Insect	Jassids per quadrat
	Assessment 2
T 1 Wynn cassia	6.08b
	(0.85)
T2 Millet	1.942a
	(1.31)
T 3 Weeds	12.49ab
	(1.13)
T 4 Bare earth	0.07c
	(0.03)
T 5 Barley Straw	4.5b
	(0.74)
p-value	0.004
Lsd (trans)	0.360

Untransformed means given in parentheses. Fisher's Lsd was calculated on the transformed scale. Treatment means have been back transformed to original scale. Lsd is untransformed (log10 y +1), means followed by the same letter are not significantly different p>0.05

A comparison of insect counts by treatment for all assessments (Table 20) identifies some interesting trends. It shows that the treatment 4 (BE) had virtually no insects present whilst the live mulch treatments had much higher numbers of insects compared to the organic mulch.

Table 20. Total insect numbers for combined assessments by treatment and species for mulch area counts

Treatment	1	2	3	4	5	Total
Jassids	80	210	142	1	57	490
Looper grub			2			2
Cricket		2			9	11
Wireworm	2	1	2		3	8
Spider	49	19	57		36	161
Parasitic wasp	2	1	2			5
Predatory beetle	76	2	36	1	36	176
Ladybird predatory	2	2				4
Earwig			2		2	4
Total	211	262	243	2	146	861
No. of species	6	7	7	2	6	

Insect diversity was similar for the mulch treatments when compared to the low diversity of treatment 4 (BE). Jassids a minor pest of capsicum, accounted for over half of all insects counted. Treatment 1 (WC) had twice the number of predatory beetles, a high spider count and low jassid numbers compared to other treatments. A review of insect numbers by assessment, shows that jassid populations were very low at the first and third assessment, but very high in the second assessment This may indicate a migration pattern, and would account for the high number of insects counted at the second assessment. Predatory insects numbers, particularly of beetles and spiders, were constant on the first two assessments but doubled on the third assessment This may indicate that these populations were more stable, and given time were able to significantly increase. This contrasts to the plant counts that show spider numbers remained constant over all assessments. Predatory beetles were constant for assessments one and two, but halved on the third assessment This contrast may indicate that the mulch area provides a more favourable environment for beneficial insects.

3.5.3 Combined crop plant counts and mulch area counts

For ease of comparison between plant counts in crop plants and in the mulch area insect numbers, data sets for the most important pests and beneficial insects are presented as a single table in Table 21. This allows the trends identified earlier to be seen more clearly. It is also clear from Table 21 that none of the major pests of capsicum were observed in the mulch area counts, whilst many important beneficial insects were observed in the mulched inter-row areas.

Table 21 Total crop plant and mulch area counts of selected insects numbers for all assessments by treatment and species

Treatment	Area	1 (WC)	2 (MI)	3 (WE)	4 (BE)	5 (BS)	Total
Aphids	crop plant count	286	715	388	1987	537	3913
	mulch area count	0	0	0	0	0	0
2 spotted mite	crop plant count	27	343	311	525	145	1351
	mulch area count	0	0	0	0	0	0
Jassids	crop plant count	0	1	0	1	4	501
	mulch area count	80	210	142	1	57	
Sub-total pests	crop plant count	313	1059	699	2513	686	5270
	mulch area count	80	210	142	1	57	490
Spiders	crop plant count	176	192	173	252	224	1017
	mulch area count	49	19	57	0	36	161
Predatory beetle	crop plant count	57	72	85	76	70	460
	mulch area count	76	2	36	1	3	161
Sub-total beneficials	crop plant count	233	264	258	328	294	1477
	mulch area count	125	21	93	1	72	312
Total	crop plant count	813	1718	1161	3335	1281	6747
	mulch area count	205	231	235	2	129	802

3.5.4 Mulch area parameters

Results of moisture level determination in the top layer of soil within the mulched area showed that the treatment 4 (BE) was much drier than other treatments, as shown in Table 22.

Table 22. Moisture content in top layer of soil within mulched area for each treatment on assessment 3

Treatment	Moisture content %*
T 1 Wynn Cassia	7.49
T 2 Millet	7.64
T 3 Weeds	5.78
T 4 Bare earth	3.5
T 5 Barley straw	7.39

Treatment 3 (WE) showed the second lowest moisture level which may be due to the more competitive nature of weed plants. Surprisingly the organic mulch treatment, treatment 5 (BS), did not have a higher moisture level than treatments 1 (WC) and 2 (MI). This may have been due to treatment 5 (BS) containing some weeds, reducing moisture conserved by the organic mulch.

The results of organic matter sampling within the mulched area for each treatment showed that treatment 3 (WE) had a much higher quantity of organic matter than other treatments.

Treatment 3 (WE) contained almost as much organic matter as treatment 5 (BS) on assessment 2 and was higher at assessment 3.

Treatment 1 (WC) had a lower organic matter content than other living mulches, but contained a higher proportion of wynn cassia plant material than treatment 2 (M1). Treatment 2 (MI) never really established itself, shown by the low content of millet plant material in the mulched area. The application of barley straw in treatment 5 (BS) at a 10 cm depth provided approximately the same total organic matter as established living mulch treatments. Living mulch treatments l(WC) and 2 (MI) were invaded by weeds, however treatment 2 (MI) was more affected than the broad leaf of wynn cassia, treatment 1 (WC).

The organic mulch inter-row area, treatment 5 (BS), was not as infested by weeds compared to treatments 1 (WC) and 2 (MI). This may have been due to the allopathic effects of barley straw decomposition limiting weed growth to the mulch edge. As plants in the living mulch treatments grew large they were slashed, adding a layer of dead organic material to the soil surface. Slashing was required because excessive growth of living mulches, particularly weeds, interfered with pesticide applications by masking the crop.

3.6 Impact of inter-row-mulches on pest and beneficial populations in a strategically sprayed crop. (Investigation 2)

Following the interesting results of Investigation 1, Investigation 2 was carried out to include different species as inter-row mulch treatments. The treatments included were white clover (WhC) (1), Wyns Cassia (WC) (2), Wyns Cassia and Rye Grass (WC+RG) (3) and Bare Earth (BE) (4)

3.6.2 Whole Crop Plant Counts

Of the total insects monitored in the crop plants over the three assessments, only a few species were found in large numbers while most of the species were present in relatively small numbers. The numbers of insects increased over the first two assessments. However, numbers decreased for many species at the third sampling. A summary of the insects found in abundance appears in Table 23. The total numbers and species of all insects monitored is included.

Table 23 Number of Insects Monitored in Whole Crop Plants By Each Assessment for all Treatments for the Most Abundant Species

Insect Species		Number counted		Total
Assessment	1	2	3	810
Aphids	58	639	113	233
Heliothis eggs	66	119	48	45
Jassids	0	35	10	9
Lacewings	0	9	0	14
Lacewing eggs	0	9	5	

*data for all these insects were analysed using an anova

The results of anova for the above species and counts of insects is included in Table 24. Significant differences ($p<0.05$) between treatments were found for Rutherglen bug, *heliothis* eggs, aphids and ladybird beetle. Rutherglen bug counts were significantly higher in treatment 1 (WhC compared to treatments 2 (WC) and 3 (WC+RG), however, treatment 4 (BE) did not show any significant differences compared to other three treatments. *Heliothis* eggs were significantly higher in treatment 4 (BE) compared to treatment 1 (WhC but was not significantly different from any other treatment. Significant effects were also observed for aphids between treatment 4 (BE), and treatment 1 (WhC). Ladybird beetles were significantly lower in treatment 4 (BE) compared to treatment 2 (WC) and treatment 3 (WC+RG) but did not significantly differ from treatment 1 (WhC). This shows that the bare earth treatment hosted more pests then beneficial insects.

Table 24 Treatment means and significance of results for total crop plants counts for all assessments

Insect species	Treatments			
	T 1 (WhC)	**T 2 (WC)**	**T 3 (WC+RG)**	**T 4 (BE)**
Rutherglen bug	125a	0b	0b	0.75ab
Aphids	64.5a	58.5a	35.5b	62.5a
Heliothis eggs	18.0a	13.75b	14.75ab	14.0b
Jassids	3.25ab	1.75b	2.25ab	3.75a
Lacewing	1.0a	0.5ab	0b	0.75ab
Ladybird	0.5bc	1.25ab	1.5a	0.25c
Lacewing eggs	1.0a	1.0a	0.75a	0.75a
Spiders	0b	1.25a	0.75a	0.75a

Other insects that showed significant effects were jassids, which are a minor pest of capsicums. Treatment 4 (BE) hosted significantly higher populations of jassids compared to treatment 2 (WC) but showed no significant differences from any other treatments.

A comparison of insect counts by treatment for all assessments is included in Table 25 and shows some interesting trends. Treatment 4 (BE) which was expected to host the most numbers of insect pests, showed very similar counts to all other treatments . However, treatment 4 (BE) also contained the greatest diversity of insect species present while the other three treatments had similar numbers of species.

Table.25 Crop Plant Insect Numbers for the Total of 3 Assessments by Treatment and Species

Insect species	Treatment				Total
	T1 (WhC)	**T2 (WC)**	**T3 (WC+RG)**	**T4 (BE)**	
Rutherglen bug	5	0	0	3	8
Aphids	228	234	142	250	884
Heliothis eggs	65	55	59	56	235
Heliothis adult	1	1	2	1	5
Jassids	13	7	9	16	45
Black f.cricket	5	2	0	1	8
Thrips	1	0	0	2	3
2 spotted mite	3	1	1	5	10
c/caterpillar eggs	0	0	5	5	10
sub-total pests	351	300	2128	339	1208
lacewing	4	2	0	3	9
Lacewing eggs	4	4	3	3	14
Parasitised helio	9	4	9	5	27
Parasitised aphids	1	0	0	0	1
Earwigs	3	1	1	5	10
Spiders	0	5	3	3	11
Big eyed bug	5	7	14	4	30
Ladybird	2	5	6	1	14
Predatory beetle	0	0	0	1	1
Parasitic wasp	2	2	3	1	8
Sub-total beneficials	30	30	39	26	125
TOTAL	381	330	257	365	1333
No of species	16	14	13	18	61

For assessment 3 a separate analysis was also carried out since this assessment was carried out one day after two consecutive days of heavy rainfall . Since the first two assessments were not carried out under similar conditions, the counts from assessment 3 may not show the same trends as assessments 1 and 2. At assessment 3 all the weeds had also been removed from all the treatments including the bare earth treatment therefore, a comparison could be carried out for counts before and after weeding the plots.

However, even when population counts were low, statistical analysis (Table 26) showed significant differences between treatment 4 (BE) and treatments 1 (WhC) and 2 (WC) for Rutherglen bugs. Significant effects were also observed for *Heliothis* eggs between treatment 4 (BE) and treatments 2 (WC) and 3 (WC+RG) where bare earth had lower populations than the other two treatments as compared to assessment 2 where treatment 4(BE) had higher populations than treatment 2(WC). Aphids were found to be significantly lower in treatment 4 (BE) than in treatments 1 (WhC) and 2 (WC) but not in treatment 3 (WC+RG). Among the beneficial insects, treatment 4(BE) surprisingly had a significantly higher population compared to treatments 1 (WhC and 2 (WC) but lower then treatment 3 (WC+RG).

Table 26 Treatment mean numbers and significance of results for crop plant counts at assessment

Insect species			Treatments	
	T1 (WhC)	T2 (WC)	T3 (WC+RG)	T4 (BE)
Pests				
Rutherglen bug	1.25a	0b	0b	0.75a
Heliothis eggs	2.0b	4.25a	4.0a	2.25b
Heliothis adults	0a	0a	1.25a	0a
Jassids	0.75a	0.25a	1.25b	0.25a
Aphids	8.00b	6.25a	2.5b	0b
Ants	0a	0a	0.25a	0a
Thrips	0.25a	0a	0a	0.5a
Cluster caterpillar	0b	0b	0.25a	0a
Beneficials				
Lacewing eggs	0a	0b	0c	0d
Lacewing adults	0b	0b	1.25a	1.25a
Parasitised helio	1.5a	0.75b	1.0ab	0.75b
Parasitised aphids	0a	0.25a	0.5a	0.5a
Spiders	0b	1.25a	1.0a	0.75ab

3.6.2 Mulch Area Counts

The mulch area counts showed a similar trends to the crop plant counts where insect numbers for the major species increased over the first 2 assessments and then decreased at the third assessment. Total insect numbers were higher in the mulch areas compared to the plant counts (which is opposite to the results obtained during the previous investigation) This could be due to the difference in the growth stages of the plant crop and the mulches, where mulches were well established and the crops were very young and was not preferred by many insects (no flowers or fruits to feed on). The anova analysis for all the insect counts in the mulch areas for all the treatments is included in Table 27.

Table 27 Treatment means and significance of results for mulch area counts for all assessments

Insect species			Treatment	
	T1 (WhC)	T2 (WC)	T3 (WC+RG)	T4 (BE)
Rutherglen bug	26.75b	27.0b	47.0a	37.5a
Thrips	125.0a	78.0c	105.5b	100.75b
Fungus gnats	32.0a	25.5b	27.0ab	16.5c
Ants	1.0b	1.75ab	3.0a	2.0ab
Jassids	10.75b	13.0ab	7.5a	14.0a
Lacewing	6.0ab	5.25b	8.25a	2.0c
Spiders	6.5a	17.25a	12.75a	15.75a
Big eyed bug	1.25b	1.75b	3.5a	1.0b
Earwig	2.25ab	3.5a	0.25b	2.0b
Ladybird	2.75a	0.5b	1.5ab	0.5b
Predatory beetle	1.75ab	1.75ab	2.25a	0.5b
Heliothis adult	0a	0.5a	0a	0.25a

Significant differences were observed for Rutherglen bugs, thrips, jassids and lacewings. Rutherglen bugs were significantly lower in treatments 1 (WhC) and 2 (WC) compared to treatment 4 (BE), however, no significant effects were observed between treatments 3 and 4. This could also have been due to heavy weed infestation in these two treatments. Thrips were significantly higher in treatment 1 (WhC) than in treatment 4 (BE) while treatment 2 (WC) was significantly lower than treatment 4. Lacewings were significantly lower in treatment 4 compared to all other treatments. This could be due to the higher number of aphids on the crop plants which were attractive to the lacewings as prey.

The total number of pest and beneficial populations over the 4 treatments shows that treatment 3 hosted the least populations which can be explained by the low cover achieved by this mulch.

The data gathered at assessment 3 was further analysed where high numbers were observed for Rutherglen bugs, thrips and jassids. Significant differences (Table 28) were observed for Rutherglen bugs between treatments 4(BE) and all other treatments where treatment 4 was significantly lower than the other 3 treatments.

Table28 Treatment means and significance of results for mulch counts at assessment 3

Insect species	**Treatment**			
	T1 (WhC)	**T2 (WC)**	**T3 (WC+RG)**	**T4 (BE)**
Rutherglen bug	10.25b	8.25b	18.0a	3.0c
Thrips	55.5a	21.0c	27.5b	0.25d
Fungus gnats	6.25a	2.0c	3.0c	5.0b
Jassids	1.5a	1.0ab	0.5c	0c
Lacewing	0.5a	0.25a	0.5a	0a
Spiders	0.25a	1.0a	0.75ab	0.5ab
Big eyed bug	0.25b	0a	0.5a	0.25a
Predatory beetle	0.25a	0.25a	0.25a	0.25a
ladybird	0.25a	0a	0a	0.25a
Earwig	0.25a	0.5a	0a	0.25a

Insect diversity in the mulch areas was fairly similar for all the treatments including bare earth which is consistent with the trend for the plant counts. Aphids and Rutherglen bugs, which are major pests of capsicums together with thrips, a minor pest, accounted for most of the insects counted during the assessments.

For both, mulch and plant counts, insect numbers increased at the second assessment while all insect numbers decreased at the third assessment. This could be largely due to the heavy rainfalls before assessment 3 which could have affected the survival of most species of insects.

3.6.3 Combined Crop Plant and Mulch Counts

For ease of comparison between insect counts in crop plant and mulched areas, both data sets for the most important pests are presented together in Table 29. This allows the trends identified earlier to be seen more clearly. It is also clear from this table that only aphids and *Heliothis* eggs were observed more in crop counts while other insects were more evident in the mulched areas.

Table 29. Total Crop Plant and mulch area counts by Treatment and Species of Major Insects for all Assessments

Insect spp.	Area	Treatments				Total
		T1 (WhC)	T2 (WC)	T3 (WC+RG)	T4 (BE)	
Rutherglen bugs	Crop	5	0	0	3	8
	Mulch	107	104	188	150	
Aphids	Crop	258	234	142	250	884
	Mulch	0	3	0	1	4
Heliothis eggs	Crop	65	55	59	56	235
	Mulch	0	0	0	0	0
Heliothis adult	Crop	1	1	2	1	5
	Mulch	0	2	0	1	3
Jassids	Crop	13	7	9	16	45
	Mulch	43	52	30	56	181
Black field cricket	Crop	5	2	0	1	8
	Mulch	10	8	3	6	27
Thrips	Crop	1	0	0	2	3
	Mulch	550	312	422	403	1687
2 spotted mites	Crop	3	1	1	5	10
	Mulch	0	0	0	0	0
C/caterpillar eggs	Crop	0	0	5	5	10
	Mulch	0	0	0	0	0
Sub-Total pests	**Crop**	**351**	**300**	**218**	**339**	**1208**
	Mulch	**603**	**377**	**455**	**467**	**1902**
Spiders	Crop	0	0	0	0	0
	Mulch	27	38	51	53	169
Lacewing eggs	Crop	6	4	3	1	14
	Mulch	0	0	0	0	0
Lacewing adult	Crop	4	2	0	3	9
	Mulch	24	21	32	8	85
Big Eye Bug	Crop	0	0	0	0	0
	Mulch	5	7	14	4	30
Pred. Beetle	Crop	0	0	0	0	0
	Mulch	7	7	9	2	25
Ladybird beetle	Crop	0	0	0	0	0
	Mulch	11	2	6	2	21
Earwig	Crop	0	0	0	0	0
	Mulch	9	14	1	8	32
Sub-Total	**Crop**	**10**	**3**	**3**	**4**	**20**
beneficials	**Mulch**	**83**	**89**	**113**	**77**	**362**
TOTAL	**Crop**	**361**	**303**	**221**	**343**	**1228**
	Mulch	**686**	**466**	**568**	**544**	**2264**
No.of Species	Crop	11	9	7	11	38
	Mulch	10	12	10	12	44

3.6.4 Mulch area Parameters

Results of moisture level determination in the top layer of soil within the mulches area showed that the treatment 4 (BE) was much drier than other treatments, as evident in Table 30.

Table 30 Moisture content in top layer of soil within mulched area for each treatment at assessment 3

Treatment	Moisture content
T I - White Clover	28.92
T2 - Wynn cassia	15.05
T3 - Wynn cassia + Rye grass	30.15
T4 - Bare earth	8.79

The results of organic matter sampling within the inter-row area for each treatment showed that at assessment 2, treatment 4 (BE) had the highest dry matter content, however, it had the lowest dry matter content at the third sampling (Table31). For the other 3 treatments, treatment 3 (WC+RG) had the highest quantity of dry matter with rye grass contributing the most. Wynn cassia had the lowest dry matter quantity over the two samplings.

Table 31 Dry weight (g) organic matter per square metre for each treatment within mulched area at assessments 2 and 3

Treatment	**Dry weight (g)**	
	Assessment 1	**Assessment 2**
TI - White clover	61.54	128.73
T2 - Wynn cassia	32.86	50.25
T3 - Wynn cassia + Rye grass	65.79	160.74
T4 - Bare earth	168.21	15.25

3.6.5 Weed Infestation

Weed infestation was most evident in treatments 4 (BE) and 2 (WC). This was largely because no weed control was carried out from the beginning of the trial, and in the bare earth treatment there was the opportunity for weeds to grow profusely. Treatment 3 (WC) did not establish very well and therefore was highly infested with weeds as well.

4.0 DISCUSSION

4.1 Strategic Pesticide Use in Trellis Tomatoes

The large scale field trials comparing treatments used as total canopy and strategic applications showed that the treatment involving canopy cover with Bt and top spraying with Larvin® was equivalent in terms of commercial yield to the complete spray treatment and better than Bt as a full canopy spray and the chemical cocktail used as a top spray. In terms of total number of anthropods the complete canopy spray with the chemical cocktail had the least, the top spray with the cocktail also with lower numbers than the Bt/Larvin Top spray and the Bt only treatment. These results are particularly interesting and show that strategic spraying provides levels of pest management resulting in acceptable commercial yields.

Strategic spraying also reduced the pesticide load in the environment and resulted in higher numbers of anthropods in the crop canopy. The reduction in pesticide use and the careful targeting of applications, in strategic spraying operations is also compatible with the introduction and more extensive use of biological control agents such as *Trichogramma* and increased biodiversity associated with living mulches and companion plantings.

These factors combined together, based on the strategic use of pesticides have considerable potential for enhancing IPM systems in subtropical and tropical vegetable production.

4.2 Integration of Biological Controls into Tomato Production

The influence of introduced and naturally occurring *Trichogramma* was investigated. Early in the crop when pest pressure was low and the damage from pests, particularly *Heleothis*, could be tolerated high levels of activity of *Trichogramma* were recorded. However as soon as routine use of insecticides commenced in the cropping area the level of parasitism by *Trichogramma* fell to almost zero. One of the important factors was the trial area, while large, was only part of a production area and therefore the major influence in the crop environment was the routine use of insecticides especially after flowering of the crop had started. The indications from this section of the work were that the combination of introduced *Trichogramma* with strategic use of pesticides, rather than blanket spraying, and inter-row planting of suitable mulch species to supporting beneficial organisms actually may be a useful IPM strategy. This required further development to produce a robust economic strategy incorporating introduced biological controls into a strategically sprayed production system.

4.3 Nozzle Technologies - wear and droplet sizes

The droplet spectra, both size and the range of sizes, produced by hydraulic nozzles is important in relation to capture and target cover and the total volume of spray required per hectare of target surface. Large 300 - 700 symbol 181 \f "Courier New" \s 12µm droplets are inefficient and both run and bounce off the target. Medium sized 150 - 300symbol 181 \f "Courier New" \s 12µm droplets fall onto the upper surfaces of target plant and soil and do not provide effective target coverage underleaves, on stems or all over fruit. Small droplets 10 -

150symbol 181 \f "Courier New" \s 12µm do provide effective and efficient coverage of plant canopies both upper and lower surfaces particularly when moving in air, wind or air movement generated by the spray. Small droplets however are prone to drift and have to be managed carefully in the crop canopy area.

Hydraulic nozzles generally produce a wide droplet spectrum. Care must be taken to select and use the most appropriate type of nozzle and pressure of operation for a particular droplet spectra. Hollow cone nozzles, in general, produce smaller droplets that flat fan or flood jet nozzles so they are more appropriate for the application of fungicides and insecticides to plant canopies. The most effective droplet size for efficient capture and target coverage is approximately 100 symbol 181 \f "Courier New" \s 12µm therefore hollow cone nozzles, producing a droplet spectra with a vmd (volume median diameter) of ?? would be the most suitable for strategic application of products to crop canopies.

The most commonly available brands of nozzles were tested at 5, 6 and 10 Bar to establish the vmd and span for each nozzle type and pressure. The results show that the large orifice sized nozzles produce larger droplets often with a vmd above 100 symbol 181 \f "Courier New" \s 12µm even at 7 and 10 Bar pressure. However the smaller orifice sizes produced droplet clouds with vmds of 80 - 100 symbol 181 \f "Courier New" \s 12µm at 5 Bar pressure. These nozzles also had droplet spectrum with a span of 1.6 indicating excessive number of large inefficient droplets. Examples of suitable nozzles operating at 5 Bar pressure were:

Lumark D2s23	vmd	97 µm	span 1.64
Teejet D2s13	vmd	88µm	span 1.84
Teeejet D2s23	vmd	96 µm	span 1.56
Albuz 1299-10	vmd	86 µm	span 1.52
Albuz 1299-08	vmd	85 µm	span 1.42
Spraying Sys Tx6c	vmd	94 µm	span 1.56

These nozzles are very appropriate for the application of pesticides to crop canopies.

The information generated on nozzles was used to advise growers and in the selection of the nozzles used in the investigations. New nozzles were used in the investigations and sets with a variance of less than symbol 177 \f "Courier New" \s 12±5% fitted to the equipment. Initially all the sprayers tested for use in the investigations had nozzle set with a variance outside this range and individual outputs of 10% more than new nozzles and were therefore not suitable for spraying targets uniformly and were discarded. Nozzles are available made from a wide range of materials and wear at different rates. They need to be monitored regularly, each day of use, and discarded then they are worn out. Growers initially disregarded this advice however by the conclusion of the project field work grower co-operators and others had established replacement programmes for nozzles. Strategic use of pesticides requires that droplets with a high potential for capture by the correct targets are produced by spraying equipment and the information on hollow cones nozzles is particularly important. Refer to Appendix (II) for the detailed information on Hollow cone nozzles.

4.4 Impact of strategic pesticide use on the pest/beneficial ratios in inter-row plantings

From the results in tables 11 and 12, it can be seen that treatments 1 & 2 (twin nozzle treatments) are significantly different from treatments 3 & 4 (single nozzle treatments). A much greater quantity of spray is deposited on to the capsicum plants using the twin nozzle application than that deposited when using single nozzles.

This must be considered carefully as the twin nozzle application (55.6μm) is applying 31% more spray than the single nozzle treatments (38.9μm). Recoveries from the plants however are only 21% higher in trial 1 and 20% higher in trial 2 for the twin nozzle treatments 1 & 2. Approximately 33% of the extra chemical applied is lost in contamination and drift. How much chemical needs to be applied to effectively control the pest population? It was suggested by Poeffling (1989), that insecticide rates and volumes could be reduced substantially and similar control of pests maintained whilst increasing the selectivity of pesticides to favour beneficials present in the agro-ecosystem. To accurately determine the rate of application that would give effective pest control efficacy further investigations are required in this cropping system

Air assistance is used to increase the penetration of sprays into the inner canopy, reduce drift and improve spray deposition (Hislop 1991). In spray trial 1 significant differences were found between the amount of dye deposited on the outer canopy when compared to that deposited on the inner canopy (table 10) for all treatments applied. There was no difference shown between the air assisted and nil air treatments suggesting in this case that air is not aiding in the penetration of the sprays.

Contamination of the inter-row spacings was higher when air assistance was used as the data in figure 12 shows when compared to treatments 2 & 4, the without air treatments. Similar results were obtained in the second investigation (figure 13) with the twin nozzle without air treatment (treatment 4) causing the least contamination of the inter-row. The deposits in the inter-row from the single nozzle treatments (treatments 3 & 4) in this investigation however, were very similar. As the capsicum plants in the second investigation were immature they were not divided into upper and inner canopy for deposit analysis so no comparisons can be made using this data.

The lack of penetration into the canopy may be of benefit however, as beneficials in the crop may escape the effects of pesticides by moving to or remaining under or in the inner canopy. Pests surviving the pesticide treatments will provide a vital food source for beneficials remaining in the crop.

Significantly less dye was deposited in the lower region of the capsicum plants than in the upper region. The spray rig was configured with three nozzles providing coverage over the top region of the plants with an additional four nozzles providing coverage to the upper region from side droppers. The lower half of the plant received coverage from four side nozzles only. This will aid in the survival of beneficials living under the plastic mulch and around the base of the capsicum plants.

Dye deposits in the inter-rows in trial 1 using ground sticks (figure 12) were very high in comparison to that actually recorded in the mulch (figure 13) in trial 2. This was due to the spray run off from the surface of the air bags. Overspray collects in the bottom of the bags and is released into the inter-rows. This was detected on the groundsticks as they provided a complete profile across the inter-row, whereas with the random sampling performed in the mulch it is unlikely that this will be detected.

This may be a problem when trying to protect beneficials in the living mulch as the contamination of the inter-row is particularly high in places. The dye deposited on the groundsticks was up to four times higher than that deposited in the crop and ten times that found when sampling the mulch (figure 13). However these high deposits may be localised and not spread throughout the inter-row area.

The overall mean deposits on the capsicum plants (Table 14) are higher than those obtained in the first investigation (Table 12) due to the different maturity levels of the crop. The plants sprayed in the second trial were much less developed and had a smaller total leaf area. This resulted in a higher concentration of dye being collected on the leaves of the plant.

The second spray trial was conducted with the same number of nozzles operating on the spray rig as in the first trial to allow comparison between the trials. However this doesn't reflect the normal practices of the grower. In this case the upper set of side nozzles would have been turned off to conserve spray unless the plot was weedy (Halpin, pers. com).

Deposits in the mulch were low in comparison to that obtained in the crop and are surprising given the size of the crop (approximately 25 cm tall) when spraying took place. Differences between treatments 2, 3 & 4 are minimal however, and when the deposits recorded on the groundsticks are also considered preservation of beneficials is most likely to be enhanced by the use of single nozzle treatments without air.

Dry matter yields (figure 14) were determined for capsicum plants growing in the three mulch treatments and compared to those growing in the bare earth treatment, to determine the competitive effects of the mulches on the capsicum crop. Although no significant differences were found between treatments, the rye grass and white clover mulches appear to be affecting the growth of the crop even at this early stage of sampling. Differences at this stage of crop development would be minimal and it will be important to perform further measurements to determine if the mulches will affect the final crop yield.

As this trial was conducted in a commercial environment the results obtained are constrained by the same factors that affect growers in their normal operations. The results obtained do not portray those that may be obtained in a controlled environment however this is seldom the case in a production situation. Significant differences were obtained between treatments which for the preservation of beneficials seemed to contradict standard spraying practices, with the expectation that air assistance would enhance deposits on the crop and reduce inter-row contamination.

The first investigation showed pesticide contamination in the inter-row area was too high for reliable survival of beneficial insects in the inter--row. However, in the second investigation, after sprayer modifications contamination was reduced, therefore increasing the possibility of beneficial survival.

From this second investigation it was shown that:

1. Air assistance during pesticide application greatly reduced the inter-row row contamination when using strategic nozzle angles.

2. The use of twin nozzles upon the spray rig was associated in both trials with higher off-target pesticide losses particularly in both the inter-row spaces and the mulches or bare earth in this area.

3. The overlap between the bottom and middle set of nozzles on each dropper gave much higher than necessary deposition levels upon the lower canopy.

4. Single nozzles when strategically angled and used with air assistance gave good crop deposition and minimised inter-row contamination.

Compared with the first investigation, the inter-row mulch contamination was markedly reduced.

4.5 Integration of living and organic mulches into IPM for vegetables

4.5.1 Impact of inter-row-mulches on pest and beneficial populations in a strategically sprayed crop. (Investigation 1)

(The results show that there are significant differences between treatments in the numbers of insect observed (Tables 16 and. 17). Results also include significant differences in numbers for the major pests of capsicum, aphids and two-spotted mites (Table 18). The trends shown m the results suggest that some beneficial insects may be favoured by mulch treatments. Overall, the mulch treatments~ treatments 1 (WC), 2 (M1), 3 (WE) and 5 (BS), resulted in higher beneficial to pest ratios and significantly lower numbers of aphids when compared to the standard industry practice of bare earth inter-rows, treatment 4 (BE).

The higher aphid populations observed in the bare earth treatment compared to other treatments is consistent with Costello & Altieri. 1994, and the information presented in tables 15 and 16 (Altieri 1987). These studies showed that the light reflectance patterns due to living mulches were possibly less attractive to aphids than clean inter-row cultivation The same argument could possibly be applied to organic mulches, as these would also alter reflected light patterns.

The number of two spotted mites recorded was highest in treatment 4 (BE), but these were not significantly different from treatment 2 (WC) and treatment 3 (WE). Separation of means within these treatments using the Lsd statistic was not possible despite the treatment 4 (BE) mean number being twice that of the nearest treatment mean number, treatment 2 (table 18). High counts of mites in the bare earth treatment might be due to the drier conditions preferred by mites (Hamilton 1991). An analysis of the top layer of soil within the mulched areas, did show that that the bare earth treatment had low moisture levels, as shown in Table 22. An additional factor may be that mulch treatments also increased humidity levels within the crop area.

Some lack of differentiation between the results for living mulches may be explained by treatments 1 (M) and 2 (M1) failing to out-compete the normal weeds present. Both these treatments contained huge numbers of established weeds. Treatment 2 (W established well initially, but millet plants were almost non-existent by time of assessment 2. Treatment 1 (M) established slowly., gradually increasing its spread over time, but never occupied the major percentage of the intercrop area. Wynn cassia is reported as a predominantly summer growing species (Oram 1990) which may explain the slow growth , but it may be better adapted to compete with weeds or other pasture species. Treatment 3 (WE) provided the same organic matter quantity over time as the organic mulch treatment 5 (BS). Other living mulches such as treatment 1 (WC), were not able to provide the same high level of organic matter. The provision of reasonable quantities of organic matter, living or non-living, by mulch treatments may be important for colonisation by insects. This may be particularly relevant in the early part of crop growth to attract beneficial insect species, when crop plants are most susceptible to insect pest attack.

Although an economic analysis of treatment establishment and maintenance costs has not been undertaken, additional costs such as slashing would be a disadvantage of some living mulch treatments. in this respect, treatment 1 (WC) as a low growing prostate plant, may offer significant advantages over weeds and other large plants as a living mulch material.

Despite the living mulches becoming infested with weeds, making detailed individual mulch treatment comparisons difficult some interesting trends were apparent The comparisons that are most interesting are those between mulch treatments, treatments 1 (WC), 2 (NM), 3 (WE), and 5 (BE), and the standard industry practice of treatment 4 (BE),with bare earth inter-rows maintained using herbicide.

The data presented in Table 21 indicates that for the two major pests of capsicum, mites and aphids, the treatment 4 (BE) counts far exceed that of any mulch treatment. Both pests were only associated with the crop plant and not found in the inter-row mulched area. Jassids were recorded in the mulch treatments being found in the mulch area, however they were not found in the associated crop plants. Spider and predatory beetle numbers were highest in the mulch treatments, treatments 1 (WC), 2 (M1), 3 (WE), and 5 (BE), compared to the treatment 4 (BE). Predatory beetle numbers in crop plant areas for all treatments were similar, however the mulched area counts per treatment showed higher total numbers of additional beetles present in the mulched area. This effect was most pronounced for treatment 1 (WC), which had the highest incidence of flowering plants. Beetles are known to seek pollen and nectar as a food source (Hassan 1995), which may explain this result A comparison of all treatments indicates treatment 1 (WC) has been most effective in reducing pests and supporting higher numbers of beneficial insects. It is disappointing that this trend has not been confirmed by statistical analysis of the results.

Environmental influences including light reflectance and moisture may be most likely to explanation of the significant effects on aphid and two-spotted mite populations by the mulch treatments. These results generally fit into the hypothesis of resource dilution as the major influence by the mulches proposed by Altieri in 1987). Predatory beetles appear to be the main beneficial insect influenced by the mulch treatments with higher populations m treatments 1 (WC), 3 (WE) and 5 (BS). This effect was most pronounced in treatment 1 (WC), with large numbers of flower, supporting the natural enemies hypothesis of Altieri (1987), and its relationship to the provision of floral food sources. Total spider numbers were not increased by diversification of the environment however they were spread over a wider area in mulched treatments being in both the crop plant and inter-row mulched areas, which provided a more diversified habitat (Table 21).

These observations suggest that cultural control effects due to diversification of the environment have been most important in reducing major insect pest numbers. Increased biological control may also have been provided by predatory beetles in mulched treatments. It is interesting to note that m treatment 1 (WC), predatory beetle populations were the highest of any treatment and mite- populations were the lowest of any treatment (table 21).

The use of a strategic spraying system using an air assisted hydraulic sprayer that targets the crop more accurately appears to have been effective in reducing pesticide deposition in the mulched areas This is highlighted by the large populations of insects most of which are beneficial, observed in the mulched areas (Table 20). Not only were insects able to survive in these areas, some populations increased over the period of the investigation.

4.5.2 Commercial Influences and Importance

The project was conducted in a commercial production situation. As a result of this and the need for large treatment plots to enhance the realism of treatments, only four degrees of error freedom for testing treatment effects were possible. In addition, the background influence of the normal pesticide program has possibly prevented the mulch treatments showing their full expression. Ideally each treatment area should be monitored independently using the same economic pest thresholds. .Then the individual treatments could be treated with an appropriate pesticide once threshold levels were reached. An additional variable that may have influenced treatment responses over time were the local weather conditions. Temperatures declined gradually over the trial period, generally below 25^{0}C These low temperatures may have accounted for the low *heliothis* pest pressure throughout the investigation.

Even considering the limitations placed upon these investigations, it is encouraging that significant differences between treatments were recorded. This indicates that the potential for mulches to influence pest and beneficial populations is real. Provided they are not exposed to contamination by pesticides, beneficial species could be expected to be even more effective under conditions where their influence was maximised. It is important to note that the significant differences between treatments involved both the major pest and beneficial species. The standard industry practice of bare earth inter-rows, treatment 4 (BE), consistently contained more pests than any other treatment which confirms that mulches do reduce pest pressure. The participating grower, Don Halpin, was also pleased with the outcome, and intends to continue investigations. It is pleasing to see that growers are prepared to try alternative pest control strategies, and be rewarded with promising results.

4.6 Impact of Inter-row Mulches of Pest and Beneficial Populations in a Strategically sprayed Crop (Investigation 2)

4.6.1 Plant Counts

The results show that there are significant differences between treatments in the numbers of some insects observed (Table24). The high significance observed for *heliothis* and aphids in treatment 4 (BE) could have been due to the heavy infestation of the mulch areas with weeds. Ladybird beetles were significantly lower in treatment 4 (BE) compared to treatment 2 (WC) and treatment 3 (WC+RG) but did not significantly differ from treatment 1 (WhC). This shows that the bare earth treatment hosted more pests than beneficial insects.

Other insects that showed significant differences were jassids, which are a minor pest of capsicums. Treatment 4 (BE) hosted significantly higher populations of jassids compared to treatment 2(WC) but showed no significant differences from any other treatments. This indicated that there was very little differences between the three mulches while bare earth again contained a higher number of pests.

It is evident that treatment 1 (WhC) hosted most beneficial insects during the first two assessments, however, at the third assessment, treatment 4 (BE) had more beneficials than any other treatment. This is difficult to explain since it was expected that after weeding, most insects and beneficials would move to other mulch treatments where there was more food sources for these insects.

A comparison of insect counts by treatment for all assessments (Table25) shows some interesting trends. Treatment 4(BE), which was expected to host the highest numbers of insect pests, showed very similar counts to all other treatments. This could be due to the bare earth treatment being covered with weeds during the first two assessments. However, treatment 4 (BE) also contained the greatest diversity of insect species present while the other three treatments had similar numbers of species. This may again be due to the presence of many different weed plants in the bare earth treatment providing a greater diversity of food sources for the insects.

At assessment 3 (Table 25), treatment 4 (BE) generally contained the least number of insects although it had a greater diversity of species present. The lower counts could have been either due to insects migrating to other treatments when their food source was removed by removing the flowering weeds or it could have been due to the insects being washed away by the heavy downpour 2 days before this sampling.

However, even when population counts were low, statistical analysis (Table 26) showed significant differences between treatment 4 (BE) and treatments 1 (WhC) and 2 (WC) for Rutherglen bugs. Significant effects were also observed for *heliothis* eggs between treatment 4 (BE) and 3 (WC+RG) where bare earth inter-rows had a lower population counts than the other two treatments. At assessment 2 treatment 4 (BE) had higher populations of *heliothis* than treatment 2(WC). Aphids were found to be significantly lower in treatment 4(BE) than in treatments 1 (WhC and 2 (WC). Among the beneficial insects, treatment 4 (BE) surprisingly had a significantly higher population compared to treatments 1 (WhQ and 2 (WC) but lower then treatment 3 (WC+RG).

The overall decline in the numbers of most abundant species at assessment 2 could have been due to the fact that at assessment 1, the crop plants were only 2 weeks old and the mulches were not flowering therefore little food was provided for beneficials in the crop. Insects and beneficial insects could have been harbouring in the neighbouring capsicums at this stage. As the older surrounding crops were harvested, the insects then migrated to the new crop of capsicums (the trial crop). This may explain the increase in numbers at assessment 2. At assessment 2, white clover was flowering and the *heliothis* counts in the crop were significantly higher in this treatment. This could have been due to the *heliothis* adults being attracted by the flowers of white clover, and subsequently moving to the crop plants to lay eggs.

Some lack of differentiation between the three mulches could be explained by treatment 2 (WC) failing to out compete the weeds present and also being smothered by the profusely growing rye grass when included as part of treatment 3. The wynn cassia treatment had a very sparse growth, increasing its spread at by assessment three, but never occupied the major percentage of the treatment area. This is mainly because of the unfavourable climatic conditions for growth, in ie wynn cassia is a summer growing legume (Oram, 1990) but was sown at the beginning of winter. As well the bare earth treatment was not a true bare earth treatment due to the large number and species of weeds present, making comparison between the mulched and unmulched treatments difficult.

4.6.2 Mulch Area Counts

Insect diversity in the mulch areas was fairly similar between all the treatments including bare earth , which is consistent with the trend for the plant counts. Aphids and rutherglen bugs which are major pests of capsicums, together with thrips, a minor pest accounted for the most insects counted over the assessments. The results obtained from this trial show that more insects preferred the mulch areas compared to the crops. The previous investigation gave opposite results to this. This could be due to the difference in the timing of mulch and crop sowing and assessments being done at a stage where both the crop and the mulches were flowering. In this investigation, the crops had only started to flower at the third assessment, therefore comparisons between the two investigations is difficult. The differences could also be due to the different sampling methods used.

4.6.3 Combined Crop and Mulch Counts

Table 29 shows some interesting differences between the three mulches and the bare earth treatments. Treatment 1 (WhC) hosted the largest number of pests and beneficial insects, followed by treatment 4 (BE). Treatment 2 (WC) had the lowest number of pests and beneficials. This shows that some mulches may increase the number of beneficial insects on the farm, but may increase the pests numbers and species as well. However, it was also evident that most pests were found in the mulch areas compared to the crops, therefore causing less damage to the crops.

4.6.4 Mulch area parameters

The high number of insect and beneficial populations in treatment 1 (WhC) could be influenced by the high moisture levels (Table 30) present in this treatment. Dry matter content was highest in treatment 3 (WC+RG) and is consistent with the amount of cover obtained from this treatment.

Considering the limitations placed upon this investigation, it is encouraging that significant differences between treatments were recorded. This indicates that the potential for mulches to influence pest and beneficial populations is real. Beneficial species could be expected to exert even more influence under conditions where their activity was maximised by reducing as swell as strategically using pesticides. It is important note that the significant differences between treatments involved both the major pest and beneficial species. The participating grower was pleased with the outcome of this trial, even though weeds had caused some hindrance in the investigation. He was also quite pleased with the establishment of rye grass and has decided to use it as a permanent mulch on his farm to reduce erosion problems as the sandy soil on this farm is very prone to erosion on windy days.

5.0 Extension/Adoption by Industry

The extension activities describing the results of this project have included:

- A meeting of primary producers, industry personnel and government staff held in Bowen in April 199. This meeting was well attended with twenty primary producers and a total audience of 29 people. At the meeting the resistance figures for major insecticides used for *Heliothis* control were presented by Bowen Crop Monitoring Services – Dale Abbott. This led, very appropriately, to a presentation by John Harden on the project and the results including the advantages of inter-planting when combined with strategic pesticide application as part of integrated pest management strategies. The discussion at the meeting was wide ranging and detailed questions were asked by participants about the selection and use of hydraulic nozzles for targetting of sprays and droplet capture. In addition the concepts associated with the use of inter-planting and biodiversity along with strategic pesticide usage, were discussed.

- Specific presentations were made in Bundaberg during the course of the project. One was at the Annual General meeting of the Bundaberg Fruit and Vegetable Growers' Association in 1996, to which members of the other associations in the district were also invited. There was an audience of approximately 50 people, and an overview presentation was made of the results and the outcomes, particularly those associated with the appropriate selection and use of spraying equipment combined with the appropriate pesticides for strategic spraying. A second meeting was held the following year at a specially convened meeting to outline the detailed results. These included the yield information which showed that using strategic spraying resulted in a reduction in the total quantity of pesticides used, and that equivalent yields of first grade fruit were harvested from strategically sprayed crops to those from conventionally grown crops.

- The results were discussed with leading producers in the Lockyer Valley and a demonstration of sprayer calibration and set-up carried out on Rick Sutton's tomato production enterprise. This was followed by a brief discussion of the outcomes at a meeting convened by the local crop consultant, Mr. Julian Winch in 1997, to discuss developments in the industry including measuring and monitoring aspects of pesticide use in vegetable crops.

- The results of several sections of the project were presented to the First National Tomato Conference held at the Gold Coast. This conference was attended by approximately 150 delegates from throughout the Australian vegetable growing industry. The detailed results of the project were presented as four posters which drew considerable comment and discussion. Copies of these posters are included in Appendix I. The general findings were also included in the "IPM Barrel of Fortune" presentation made as part of the Conference Proceedings by Associate Professor John Harden. This interactive presentation drew a lot of audience participation and resulted in considerable follow-up discussion. Groups of growers, particularly a group from the Lockyer Valley, followed up with a request for on-going support in developing IPM, including strategic spraying strategies for crops in the Lockyer Valley. This support has been provided via the local crop consultants and on an individual basis to particular growers.

- **Grower Interaction and Response.** SP Exports, particularly Mr. Andrew Philip, have discussed the outcomes of the project with a wide range of visitors from within and outside the State. In addition to provision of large areas of crop and access to spraying equipment, as a major co-operator during the project, SP Exports have been keen to promote the results and combine them into the establishment of inter-planting systems involving a range of possible species. These intercrop plantings were designed to host beneficials as well as changing the microclimate within the cropping systems, and when combined with strategic spraying, reduced the reliance on pesticides for pest management in commercial crops.

- One of the major outcomes of the project has been the change to the spraying systems used within the industry. SP exports were the first to build a strategic sprayer and as a result of the project's findings have fitted GPS systems to two large strategic spraying units. This is to enable the careful monitoring of this location and speed of the sprayers not fitted with appropriate strategic spraying equipment and control systems.

- **Halpin Farms,** under the management of Mr. Don Halpin, provided access to crops of capsicums and considerable support for project activities on his farm. Mr. Halpin, following previous advice, had constructed an air assisted hydraulic sprayer with the air movement produced by hydraulic fans fitted to a small air bag with outlets around each nozzle body. This sprayer was examined, its performance assessed and then set up to maximise the capture of pesticide in the crop and minimise the losses into the inter-row spaces. The performance of this strategic sprayer was assessed and Mr. Halpin assisted in making it into a strategic sprayer.

  This spraying equipment was then used in commercial crops using conventional pest (insect, plant disease and weed) control approaches. These included use of herbicides to control all inter-row weeds, and miticides, fungicides and insecticides for other pests.

The success of the strategic sprayer indicated that pesticide contamination of the inter-row and headland spaces could be minimised. This result was compatible with the growth of companion and inter-row plants to maximise the activities of beneficial organisms which would reduce the incidence of pests (see figure 19).

Figure 19 : A commercial capsicum crop at Mr. Don Halpin's farm where white clover is being used as an inter-row mulch.

The trials combining the use of strategic spraying with interplanting of white clover and other species showed that pesticide use could be reduced while yields of first grade capsicums were higher in interplanted compared to conventionally grown crops. These results have attracted a lot of attention from other producers, Government and industry extension staff and Mr. Halpin has adopted the system on his farm . He has developed planting/mulch laying equipment to establish the companion plants well before planting out capsicums (see figure 20) and refined the use of the strategic sprayer with careful selection of pesticides, using the advice of Crop Tech consultants. This provides an excellent example of the commercial outcomes of the project even though the complete production system requires further refinement.

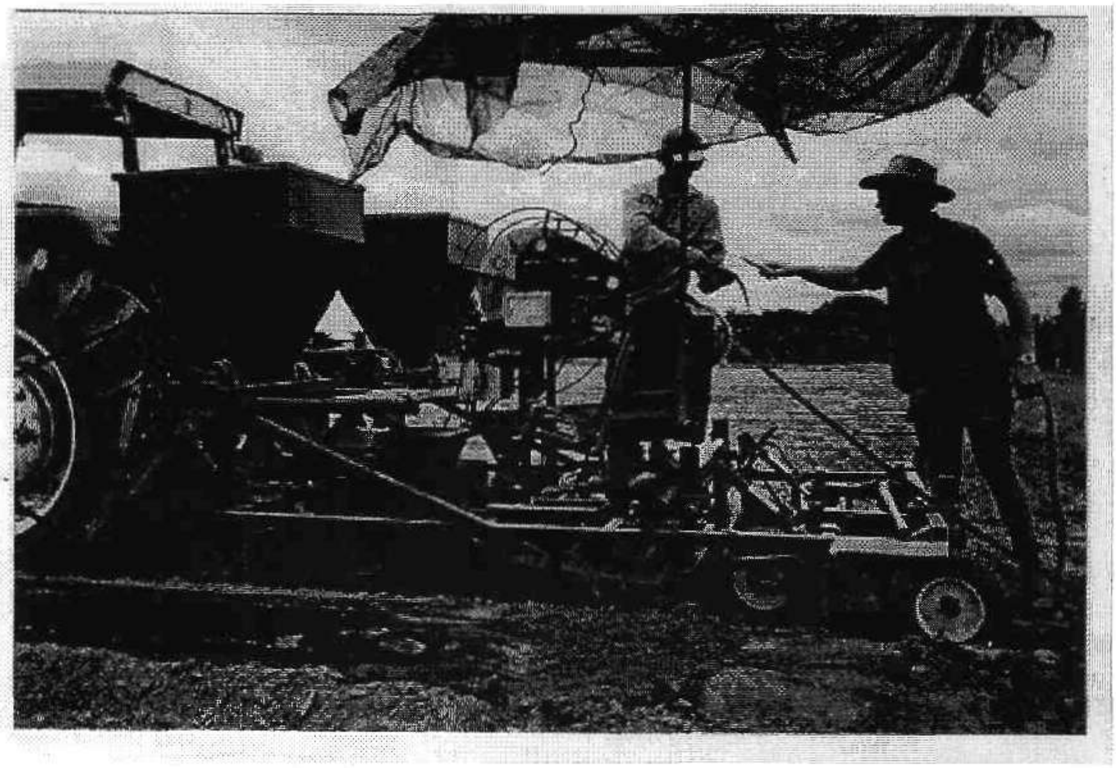

Figure 20 : Plastic mulch layer developed and built by Mr. Don Halpin to establish inter-row mulches.

- A group of senior students monitored the results of strategic spraying and companion planting compared to conventional plant protection programmes on Mr. Rick Sutton's tomato crop in the 1997 season. The results showed that equivalent levels of pest management could be delivered using strategic spraying with carefully set up and calibrated equipment. These results were discussed throughout the season with the grower.

6.0 Directions for Future Research

The results of this project indicate there is considerable potential to combine strategic pesticide use with living mulches/companion plantings as part of IPM strategies. Confining the pesticides to specific sections of crop canopies allows beneficials to develop and assist with pest management. The further investigation and development of vegetable production systems including companion plantings/living mulches is warranted.

The living mulches not only increase biological diversity and host beneficials they change the crop microclimate, increase return of organic material to the soil, and reduce erosion. These are all important to the development and maintenance of sustainable vegetable crop production systems. Maximising the usefulness of companion plantings in IPM strategies required strategic use of pesticides to minimise disruption of both pests and beneficials in these areas.

There is a need to investigate plant species suitable for use as companion plantings/mulches in relation to particular vegetable crops, various and soil types/environments. In combination with this spraying systems will need to be modified to spray particular targets.

7.0 Financial Commercial Benefits of Adoption of Research Findings

Growers implementing strategic spraying, including careful pesticide selection, reduce costs of plant protection immediately. Savings are made both in number and quantity of pesticides and in the amount of carrier required to apply them. There is a reduction in spray carrier use, water, time and wear and tear on spraying equipment. Section and use of appropriate nozzles has reduced the spray volume required for mature tomato crops from 2000 h/ha to 1000 h/ha. This is a saving of 50%.

Strategic spraying has also resulted in an increase in activities of beneficial organisms and a considerable reduction of crop threatening pests such as leaf minor in tomatoes and mites in capsicums. The combination of strategic pesticide use and companion plantings has further enhanced the influence of beneficials and reduced the level of pests such as bacterial spray in capsicums. This combination enhances crop growth, stabilises the crop production system and is sustainable into the future.

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Appendix 1 - List of Investigations That are Included in this Report

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Stevens, P.M. (1995) The Importance of Living and Organic Mulches in IPM for Vegetables Study Project Thesis, School of Land and Food, University of Queensland, Gatton College.

Stevens, P.M. (1995) Unpublished data on Nozzle wear and droplet sizes, School of Land and Food, University of Queensland, Gatton College.

Taylor, I (1996) The Impact of Strategic Pesticide Use on the Pest/Beneficial Ratios in Inter-row Plantings of Vegetables Study Project Thesis, School of Land and Food, University of Queensland, Gatton College.

Appendix 2 - Nozzle Technology Data

(Complete details of nozzle information attached after page 84. (page No 1-27))

APPENDIX 3 - Tomato Conference Posters

THE IMPORTANCE OF HYDRAULIC NOZZLE SELECTION

CONTRIBUTORS	SUPPORTED BY:-
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IMPORTANCE NOZZLE SELECTION

Hydraulic nozzle selection is an important part of pesticide use And IPM. Nozzle selection and operation determines the droplet characteristics, flow rates and the canopy / target capture of droplets. Understanding the characteristics of nozzles and their relationships with different products and the spraying unit is an essential part of developing efficient pesticide use systems.

NOZZLE RESEARCH

In developing and refining application systems a wide range of nozzles have been evaluated. Features including droplet size and flow rates of new nozzles were examined in relation to spraying pressures. In particular nozzle wear and deterioration caused by abrasive pesticides such as copper fungicides was also measured in commercial spraying situations.

NOZZLES AND PRESSURE

Pressure directly influenced nozzle performance. High pressures reduced droplet size and increased flow rates with all nozzle types tested. Nozzle orifice size directly influences droplet size and flow rate. The smaller the nozzle orifice and the higher the pressure the smaller the droplets. Small droplets of approximately 100um are the most effective and efficient for applying insecticides and fungicides to vegetable crops.

NOZZLE TYPE	PRESSURE (BAR)	FLOW RATE (ml)	VMD (um)	SPAN
LURMARK	5	390	89	1.6
D2s13	7	450	78	1.54
	10	530	71	1.56
LURMARK	5	510	97	1.64
D2s23	7	600	88	1.65
	10	700	88	1.73
LURMARK	5	790	129	1.58
D2s25	7	930	129	1.55
	10	1100	125	1.58
LURMARK	5	580	105	1.49
D3s23	7	680	102	1.64
	10	800	94	1.69
LURMARK	5	940	144	1.58
D3s25	7	1130	140	1.56
	10	1340	137	1.59
LURMARK	5	1150	175	1.53
D3s45	7	1330	166	1.51
	10	1600	154	1.58

Table 1 shows the characteristics of the range of hollow cone nozzles available from Lurmark. Note that by increasing pressure the mean droplet size decreases and flow rate increases.

NOZZLE WEAR

Use of abrasive materials and dirty water has a marked effect upon nozzle wear and performance. In a normal spraying program which includes frequent use of fungicides, it has been found that nozzles can degrade rapidly and require replacement often on a monthly basis. Flow rates have been found to increase by up to 25%. This represents a substantial overuse of pesticides, production of the wrong droplet spectrums and therefore lowered crop canopy / target droplet capture. (See figure 1)

CONCLUSIONS

- Use small orifice hollow cone nozzles with a medium pressure of 5 - 7 bar for fungicide and insecticide application.
- Measure flow rates at least weekly during season.
- Discard nozzles when flow rate increases by 10%.
- Check new nozzle outputs to confirm that all are within 10% of the average output.
- Ensure that pressure gauges are accurate.
- Nozzles of the same size from the different manufacturers produce equivalent droplet spectrums.

Nozzles will wear at different rates depending on the:-

Nozzle construction material.

Pesticides Used.

Sprayer operating pressure.

Water Quality.

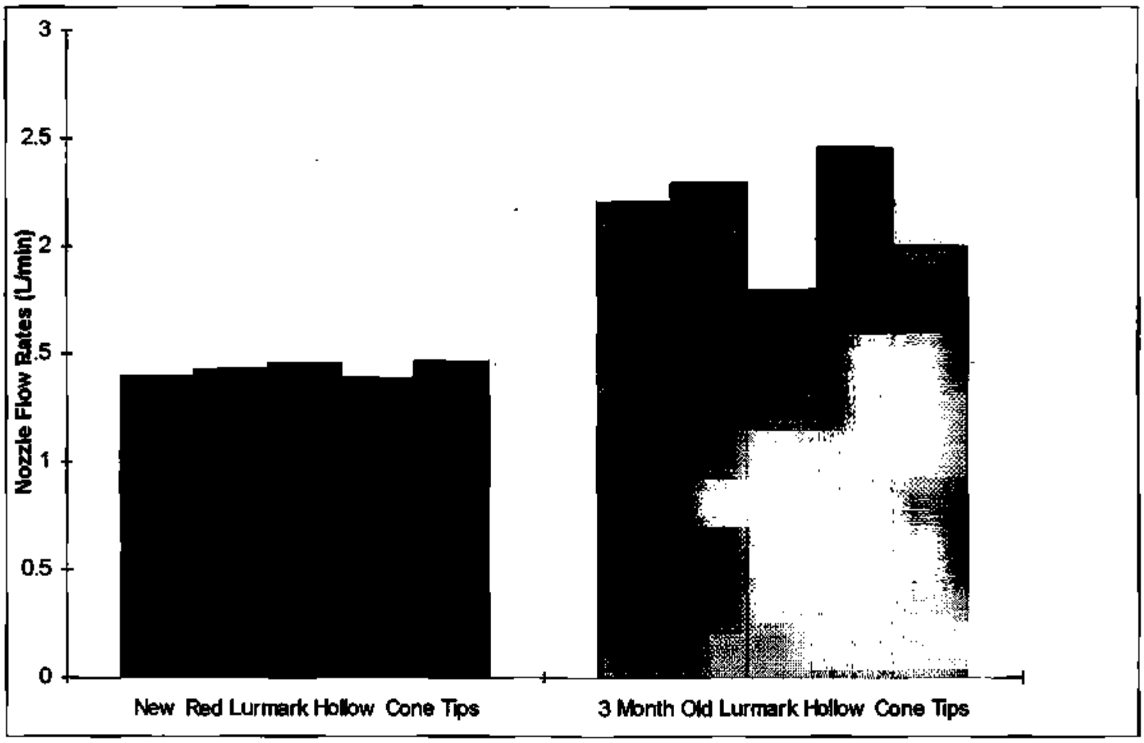

Figure 1 : Comparison of nozzle flow rates between new and 3 month old nozzles.

STRATEGIC PESTICIDE APPLICATION IN VEGETABLE PRODUCTION

CONTRIBUTORS	SUPPORTED BY:-
Associate Professor John Harden, Tonia Loughrey, Ian Taylor, Paul Grundy and John Hall.	**The University of Qld - Gatton College**
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University of Queensland, Gatton College, Lawes 4345.	**Queensland Fruit & Vegetable Growers**
Crop Tech Laboratories, Langbeckers Rd, Bundaberg Qld. 4670.	

WHAT IS STRATEGIC APPLICATION

Strategic Application reduces the untimely use and unnecessary contamination of off target areas and directs valuable pesticides towards target pests only. When strategic use is combined with natural enemies and living mulches, biological control is enhanced.

STRATEGIC APPLICATION RESEARCH

Strategic pesticide application was examined for its potential to maximise biological control and to minimise pesticide resistance and costs. Existing application technology was assessed and improvements sought. Aspects considered included the use of air assistance, pressure, nozzle types and nozzle positioning upon sprayers. Applicator configurations were tested using fluorometric analysis to identify crop target and off target deposit levels.

STRATEGIC APPLICATION RESULTS

1. Mulch contamination was minimised with air assistance and low spray volumes.

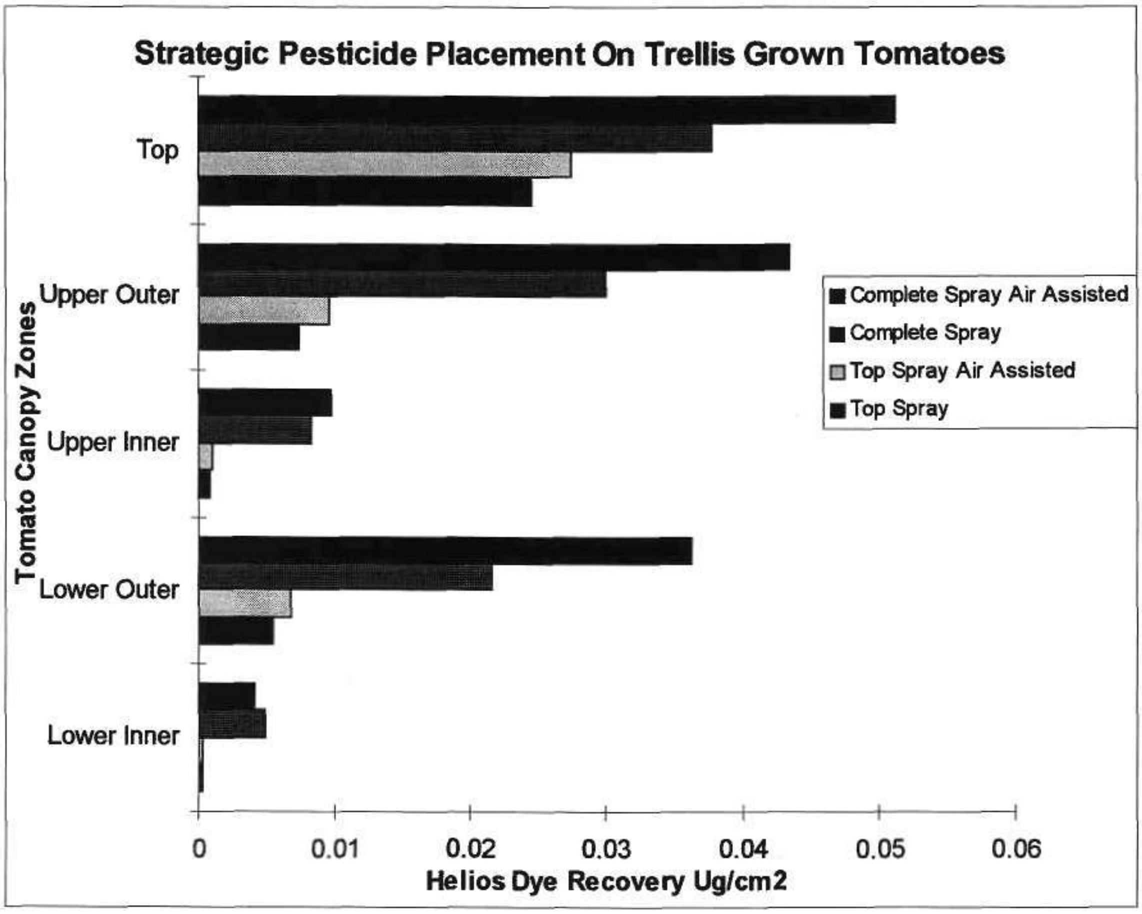
2. High volume application increased pesticide losses and did not greatly improve canopy capture.

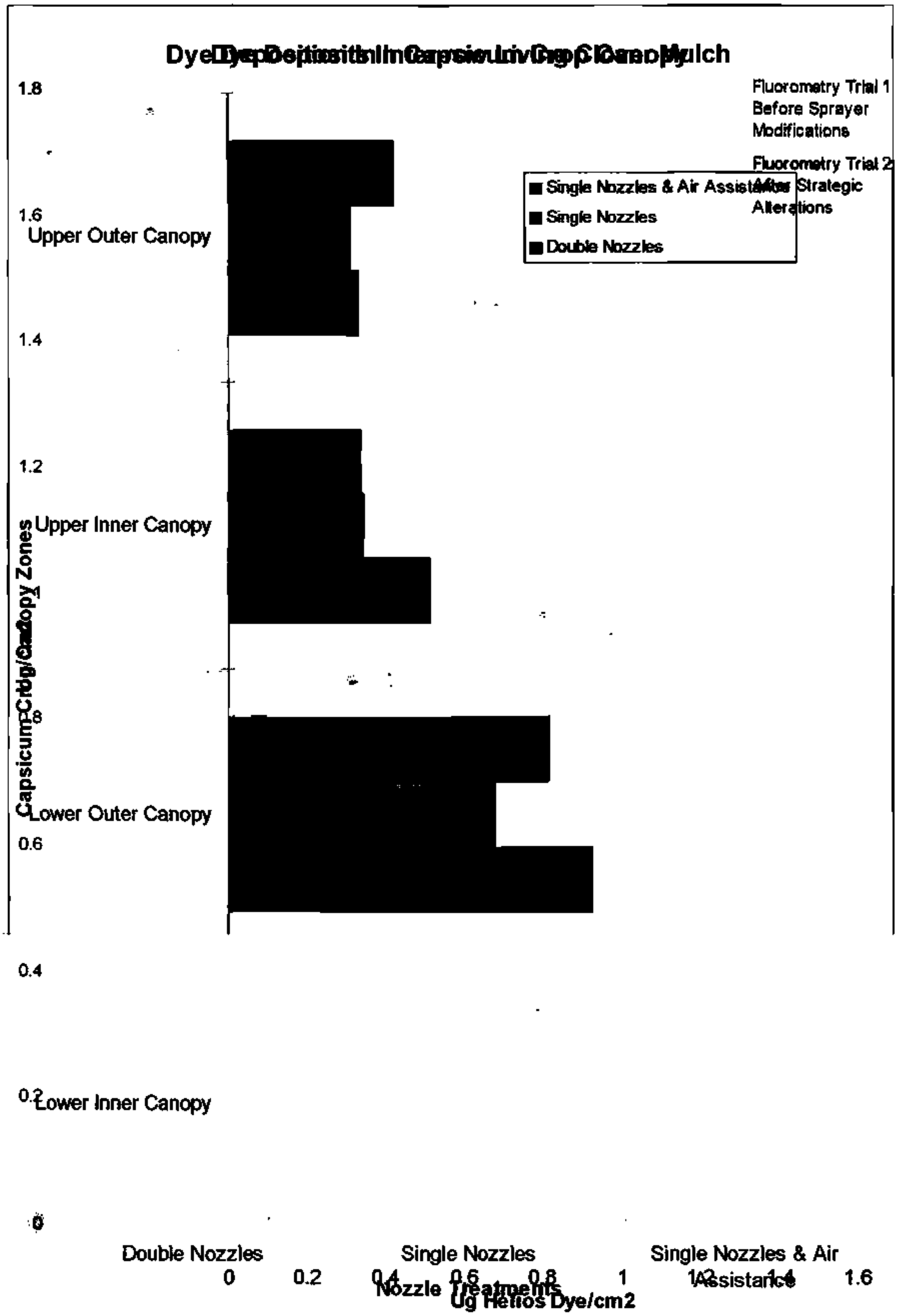
3. In trellised tomatoes, canopy sections can be treated according to pest pressure and location.

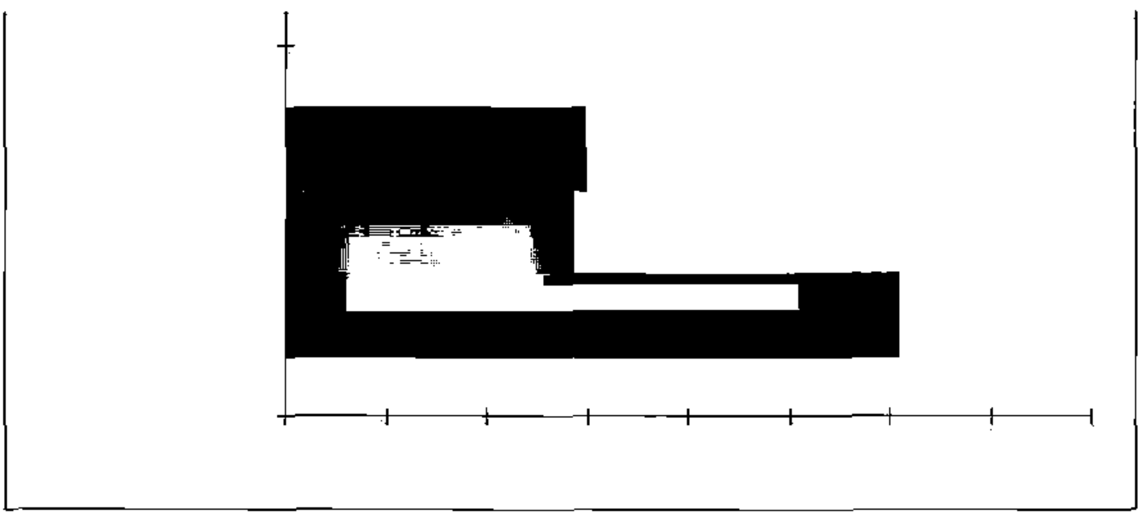
4. When combined with appropriate pesticide selection, strategic application can minimise natural enemy losses, resistance development and environmental contamination.

CONCLUSIONS

Strategic application minimised off target losses, lowered overall spray volumes and increased crop canopy capture efficiency which preserved beneficials in the inter-row mulches and reduced application expenditure.




Fluorometry Trial 1
Before Sprayer
Modifications
Fluorometry Trial 2
Strategic
Alterations
Single Nozzles & Air Assist
Single Nozzles
Double Nozzles
1.8
1.6
1.4
1.2
0.6
0.4
0
Upper Outer Canopy
Upper Inner Canopy
Lower Outer Canopy
Lower Inner Canopy
Double Nozzles
Single Nozzles
Single Nozzles & Air
0
0.2
1
1.6
Dye/cm2



LIVING MULCHES IN VEGETABLE PRODUCTION

CONTRIBUTORS	SUPPORTED BY:
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WHAT ARE LIVING MULCHES ?

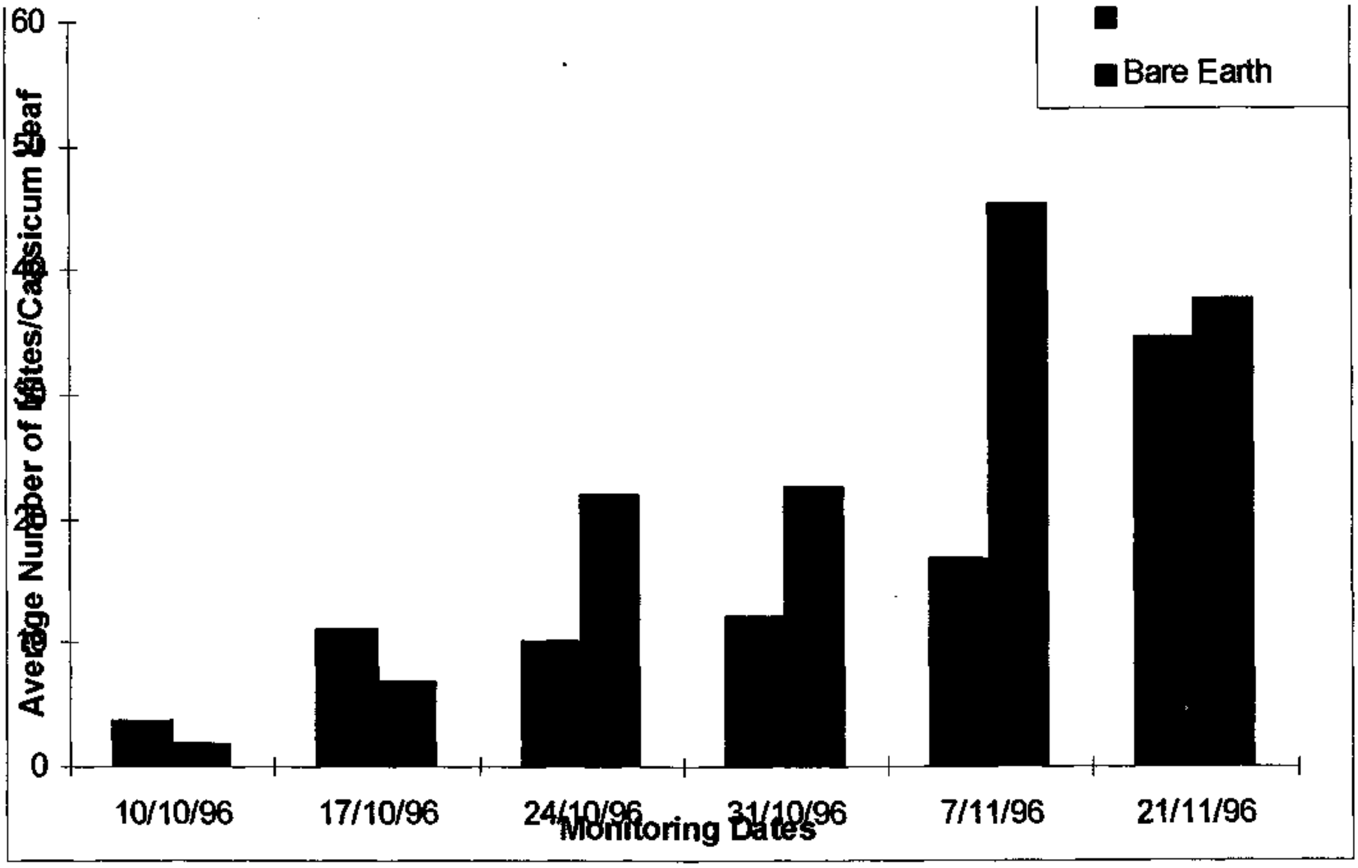
Living Mulches are preferably leguminous species which are established with in the crop interow and headland areas at the beginning of the season.

WHY USE LIVING MULCHES ?

Living mulches provide food, shelter and protection from pesticide exposure for natural enemies by increasing biological diversity.

LIVING MULCH RESEARCH

A series of living mulch trials have been conducted using rye grass (*Lolium* spp.),peanuts, white clover (*Trifolium repens*), natural weedy complexes and wynns cassia (*Chamaecristarotundifolia)* in capsicum and tomato crops. Mulches have been compared with bare earth practices for benefits including improved biological control, soil sustainability and fruit quality.



LIVING MULCH RESULTS
Living mulches field trials have shown that :-

1. Natural enemy activity is increased with mulches.

2. Predatory mites are more abundant with mulches.

3. Non-invasive mulch species such as white clover did not lower yields.

4. Quality aspects were increased by minimising heat damage, "sand blasting" and mud splash.

5. Soil organic matter and nematode antagonists increased.

6. Living mulches protected natural enemies from pesticide exposure.

CONCLUSIONS
Living mulches significantly increased natural enemies in the crop and preserved them by supplying habitat and shelter from pesticide fallout particularly when combined with strategic pesticide application minimising interow contamination. Yield and fruit quality was also increased when using living mulches.

Results	Time	0.10	VMD / 0.5	0.90	4,3	3,2	span
Lurmark d2s13 5 bar	19-Dec						
nozzle 1-1	13:53:24	40.30	91	189	106	69	1.63
nozzle 1-2	13:54:38	39.73	89	179	102	62	1.57
nozzle 2-1	13:55:22	39.60	87	169	99	67	1.49
nozzle 2-2	13:55:56	39.64	86	168	98	66	1.48
nozzle 3-1	13:56:33	39.59	91	187	105	66	1.62
nozzle 3-2	13:57:08	40.01	91	190	106	67	1.64
nozzle 4-1	13:57:50	38.53	84	157	93	59	1.41
nozzle 4-2	13:58:28	37.89	84	158	93	59	1.42
nozzle 5-1	13:59:05	39.96	93	213	114	70	1.86
nozzle 5-2	13:59:41	39.90	93	214	114	71	1.87
teejet d2s13 5 bar	19-Dec						
nozzle 1-1	13:41:10	41	86	166	97	62	1.45
nozzle 1-2	13:41:51	42	87	165	97	66	1.41
nozzle 2-1	13:42:32	41	89	174	100	61	1.51
nozzle 2-2	13:43:14	42	90	175	101	63	1.49
nozzle 3-1	13:44:13	41	88	175	100	63	1.52
nozzle 3-2	13:44:51	42	88	173	100	64	1.50
nozzle 4-1	13:45:31	40	89	172	100	63	1.48
nozzle 4-2	13:46:09	41	89	172	100	63	1.48
nozzle 5-1	13:46:47	40	86	168	97	62	1.49
nozzle 5-2	13:47:26	40	86	167	97	62	1.49
delavan d2s13 5 bar	19-Dec						
nozzle 1-1	14:18:01	52	126	270	147	95	1.72
nozzle 1-2	14:18:46	53	125	269	146	95	1.72
nozzle 2-1	14:19:23	51	122	319	160	94	2.20
nozzle 2-2	14:20:51	53	123	274	148	94	1.80
nozzle 3-1	14:21:31	43	93	166	101	70	1.33
nozzle 3-2	14:22:13	44	93	166	101	71	1.31
nozzle 4-1	14:22:50	45	101	195	113	76	1.50
nozzle 4-2	14:23:57	44	100	194	113	76	1.51
nozzle 5-1	14:24:32	58	142	300	166	106	1.70
nozzle 5-2	14:25:09	57	140	287	158	103	1.65
Albuz 1299-08 5 bar	19-Dec						
nozzle 1-1	14:31:31	39	89	168	99	65	1.44
nozzle 1-2	14:33:47	38	88	166	97	61	1.44
nozzle 2-1	14:34:27	38	87	165	96	61	1.46
nozzle 2-2	14:35:05	38	86	164	95	61	1.47
nozzle 3-1	14:35:41	38	87	160	95	62	1.40
nozzle 3-2	14:36:20	38	86	159	94	60	1.40
nozzle 4-1	14:36:57	38	82	155	90	57	1.43
nozzle 4-2	14:37:46	38	83	154	91	61	1.40
nozzle 5-1	14:38:25	38	81	152	89	58	1.41
nozzle 5-2	14:39:12	37	84	154	91	59	1.39

Lumark d2s13 7bar	14/12/94						
nozzle 1-1	14:43:22	38	77	159	90	61	1.57
nozzle 1-2	14:44:22	38	80	167	94	61	1.62
nozzle 2-1	14:45:02	35	77	147	85	54	1.46
nozzle 2-2	14:45:40	36	77	147	86	56	1.44
nozzle 3-1	14:46:18	36	81	168	94	62	1.64
nozzle 3-2	14:47:37	36	81	167	94	61	1.62
nozzle 4-1	14:48:59	36	79	157	90	59	1.53
nozzle 4-2	14:50:29	36	79	155	90	59	1.52
nozzle 5-1	14:51:31	37	79	162	92	61	1.59
nozzle 5-2	14:52:34	37	75	143	85	60	1.41
teejet d2s13 7 bar	19-Dec						
nozzle 1-1	14:59:37	37	79	153	89	60	1.46
nozzle 1-2	15:00:14	38	80	154	90	62	1.46
nozzle 2-1	15:01:08	39	80	153	91	64	1.42
nozzle 2-2	15:01:46	38	81	154	91	62	1.45
nozzle 3-1	15:02:25	38	77	150	88	59	1.45
nozzle 3-2	15:03:04	37	78	150	88	59	1.45
nozzle 4-1	15:03:41	36	75	148	86	56	1.49
nozzle 4-2	15:04:16	36	77	151	87	59	1.49
nozzle 5-1	15:04:53	36	76	146	86	58	1.45
nozzle 5-2	15:05:31	36	76	143	85	59	1.41
Albuz 1299-08 7 bar	19/12/94						
nozzle 1-1	15:59:33	37	84	159	92	63	1.46
nozzle 1-2	16:00:10	37	83	158	92	62	1.46
nozzle 2-1	16:00:45	36	80	156	90	62	1.50
nozzle 2-2	16:01:21	36	80	154	89	60	1.48
nozzle 3-1	16:02:01	35	80	150	88	60	1.44
nozzle 3-2	16:03:01	35	77	145	84	56	1.44
nozzle 4-1	16:03:37	35	77	148	86	59	1.48
nozzle 4-2	16:04:11	34	76	148	85	58	1.49
nozzle 5-1	16:04:47	34	76	146	85	59	1.47
nozzle 5-2	16:05:23	34	76	146	85	59	1.46

Lurmark d2s13 10bar	14/12/94						
nozzle 1-1	16:15:08	35	77	175	94	58	1.82
nozzle 1-2	16:16:07	33	73	166	89	54	1.83
nozzle 2-1	16:16:45	33	70	138	79	52	1.51
nozzle 2-2	16:17:28	33	69	136	78	51	1.50
nozzle 3-1	16:18:32	34	69	126	76	51	1.34
nozzle 3-2	16:19:15	33	70	128	77	53	1.36
nozzle 4-1	16:21:00	33	73	157	86	56	1.70
nozzle 4-2	16:21:38	33	72	156	85	54	1.71
nozzle 5-1	16:22:20	33	70	130	77	52	1.40
nozzle 5-2	16:22:56	33	69	129	77	52	1.40
Delavan d2s13 10bar	14/12/94						
nozzle 1-1	16:02:33	39	83	165	95	60	1.51
nozzle 1-2	16:04:01	38	85	170	97	65	1.56
nozzle 2-1	16:04:39	37	79	148	88	60	1.40
nozzle 2-2	16:05:23	36	79	146	86	57	1.40
nozzle 3-1	16:06:19	36	80	154	90	58	1.47
nozzle 3-2	16:07:24	36	79	153	89	57	1.48
nozzle 4-1	16:08:33	36	79	185	98	62	1.88
nozzle 4-2	16:09:10	36	76	176	93	57	1.84
nozzle 5-1	16:09:49	41	93	222	116	71	1.95
nozzle 5-2	16:10:43	38	88	213	110	67	1.99
Albuz 1299-08 10 bar	14/12/94						
nozzle 1-1	16:33:05	34	79	147	86	56	1.43
nozzle 1-2	16:33:43	34	79	147	86	57	1.44
nozzle 2-1	16:34:21	34	78	148	86	56	1.47
nozzle 2-2	16:35:00	33	76	146	84	53	1.48
nozzle 3-1	16:35:41	34	77	145	84	54	1.46
nozzle 3-2	16:36:19	33	77	145	85	55	1.45
nozzle 4-1	16:37:00	33	76	146	84	54	1.47
nozzle 4-2	16:38:42	33	75	144	83	53	1.48
nozzle 5-1	16:39:24	33	73	140	80	52	1.46
nozzle 5-2	16:40:02	33	75	144	84	58	1.48

Results	Time	0.1	VMD / 0.5	0.9	4,3	3,2	span
Lurmark d2s23 5 bar	16-Dec						
nozzle 1-1	8:54:45	43	93	192	110	73	1.59
nozzle 1-2	8:55:51	43	93	191	110	75	1.59
nozzle 2-1	8:56:41	46	100	217	119	79	1.70
nozzle 2-2	8:57:32	46	106	220	121	82	1.64
nozzle 3-1	9:00:46	46	86	187	106	75	1.64
nozzle 3-2	9:01:34	44	89	189	106	74	1.63
nozzle 4-1	9:02:22	45	101	213	118	80	1.66
nozzle 4-2	9:03:14	44	102	212	118	79	1.65
nozzle 5-1	9:03:56	44	97	206	115	77	1.66
nozzle 5-2	9:04:34	43	97	206	115	74	1.67
teejet d2s23 5 bar	16/12/94						
nozzle 1-1	9:34:24	42	99	200	112	67	1.59
nozzle 1-2	9:35:07	43	99	199	112	74	1.57
nozzle 2-1	9:35:59	43	98	190	110	72	1.50
nozzle 2-2	9:36:41	42	95	187	107	69	1.53
nozzle 3-1	9:37:23	41	94	188	107	68	1.57
nozzle 3-2	9:38:06	42	95	190	107	66	1.56
nozzle 4-1	9:38:46	42	92	189	106	67	1.60
nozzle 4-2	9:39:28	42	93	190	106	66	1.60
nozzle 5-1	9:42:54	42	97	189	109	69	1.51
nozzle 5-2	9:43:54	42	96	188	108	70	1.51
delavan d2s23 5 bar	16/12/94						
nozzle 1-1	9:23:21	47	134	283	151	85	1.76
nozzle 1-2	9:24:09	53	153	371	189	102	2.08
nozzle 2-1	9:24:48	54	161	378	196	106	2.01
nozzle 2-2	9:25:25	53	155	373	188	103	2.06
nozzle 3-1	9:26:06	45	116	231	129	78	1.59
nozzle 3-2	9:26:43	45	115	229	128	77	1.61
nozzle 4-1	9:27:28	43	99	202	112	69	1.61
nozzle 4-2	9:28:07	42	100	203	114	70	1.60
nozzle 5-1	9:28:49	45	119	225	129	78	1.52
nozzle 5-2	9:29:39	46	122	229	131	81	1.50
Albuz 1299-10 5 bar	16/12/94						
nozzle 1-1	9:47:21	41	91	181	104	65	1.54
nozzle 1-2	9:49:06	43	89	178	103	71	1.51
nozzle 2-1	9:49:51	41	89	174	101	68	1.50
nozzle 2-2	9:50:28	41	88	175	100	63	1.52
nozzle 3-1	9:51:36	41	85	171	98	61	1.52
nozzle 3-2	9:52:19	40	84	167	95	59	1.52
nozzle 4-1	9:53:01	41	83	166	94	60	1.51
nozzle 4-2	9:53:42	41	82	166	95	64	1.53
nozzle 5-1	9:54:20	40	84	168	95	60	1.53
nozzle 5-2	9:55:04	40	85	168	96	60	1.51

		0.10	VMD/0.5	0.90	4,3	3,2	Span
Lurmark d2s23 7bar	16/12/94						
nozzle 1-1	10:04:20	39	81	169	95	55	1.60
nozzle 1-2	10:05:00	39	83	170	96	56	1.59
nozzle 2-1	10:05:37	40	94	196	109	62	1.66
nozzle 2-2	10:06:17	40	97	198	111	63	1.63
nozzle 3-1	10:06:56	39	82	174	97	55	1.64
nozzle 3-2	10:07:39	39	81	173	96	54	1.65
nozzle 4-1	10:08:17	39	91	192	106	59	1.67
nozzle 4-2	10:08:55	39	92	193	107	61	1.67
nozzle 5-1	10:09:32	40	90	191	105	60	1.68
nozzle 5-2	10:10:14	40	90	190	105	60	1.68
teejet d2s23 7 bar	16/12/94						
nozzle 1-1	10:14:51	39	93	187	105	59	1.59
nozzle 1-2	10:15:28	39	93	187	105	59	1.59
nozzle 2-1	10:16:06	40	95	184	105	61	1.52
nozzle 2-2	10:16:42	38	92	182	103	57	1.56
nozzle 3-1	10:17:19	38	90	184	103	57	1.61
nozzle 3-2	10:17:56	38	89	180	101	58	1.59
nozzle 4-1	10:18:35	38	88	182	101	56	1.64
nozzle 4-2	10:19:12	38	87	179	100	56	1.62
nozzle 5-1	10:20:10	38	90	180	102	57	1.58
nozzle 5-2	10:20:49	39	92	180	102	58	1.55
Delavan d2s23 7bar	16/12/94						
nozzle 1-1	10:29:18	45	123	248	136	78	1.65
nozzle 1-2	10:29:57	45	123	248	137	79	1.65
nozzle 2-1	10:32:21	45	131	330	158	78	2.18
nozzle 2-2	10:33:00	45	132	334	165	79	2.19
nozzle 3-1	10:35:04	42	108	224	122	68	1.69
nozzle 3-2	10:35:43	42	111	226	124	70	1.66
nozzle 4-1	10:36:20	44	120	239	132	76	1.63
nozzle 4-2	10:36:59	45	122	240	134	78	1.60
nozzle 5-1	10:37:42	42	110	227	125	71	1.68
nozzle 5-2	10:38:20	42	109	222	123	71	1.65
Albuz 1299-10 7 bar	16/12/94						
nozzle 1-1	10:45:59	38	88	176	100	57	1.56
nozzle 1-2	10:46:39	39	87	176	100	56	1.58
nozzle 2-1	10:47:15	38	89	175	99	56	1.53
nozzle 2-2	10:47:55	38	89	174	99	56	1.53
nozzle 3-1	10:48:33	38	88	168	97	55	1.48
nozzle 3-2	10:49:12	38	85	166	95	53	1.49
nozzle 4-1	10:49:52	38	83	166	94	52	1.54
nozzle 4-2	10:50:33	37	81	163	92	51	1.56
nozzle 5-1	10:51:13	37	83	164	93	52	1.52
nozzle 5-2	10:51:53	37	82	164	92	49	1.54

Lurmark d2s23 10bar	16/12/94						
nozzle 1-1	10:58:01	37	89	191	105	56	1.73
nozzle 1-2	10:59:20	37	90	195	105	55	1.75
nozzle 2-1	11:00:00	36	89	193	105	57	1.75
nozzle 2-2	11:01:19	36	86	189	102	53	1.78
nozzle 3-1	11:02:39	37	93	194	107	58	1.69
nozzle 3-2	11:03:15	37	93	197	107	58	1.73
nozzle 4-1	11:03:54	36	80	172	93	48	1.71
nozzle 4-2	11:04:34	35	81	173	94	49	1.70
nozzle 5-1	11:05:16	37	88	190	103	54	1.75
nozzle 5-2	11:05:53	36	88	189	103	55	1.75
teejet d2s23 10 bar	16/12/94						
nozzle 1-1	11:11:07	37	94	184	104	57	1.56
nozzle 1-2	11:11:52	36	93	182	103	56	1.56
nozzle 2-1	11:12:33	36	93	179	102	55	1.55
nozzle 2-2	11:13:26	35	86	170	96	50	1.58
nozzle 3-1	11:14:08	35	86	173	97	51	1.60
nozzle 3-2	11:14:48	35	86	174	97	50	1.62
nozzle 4-1	11:15:40	36	89	177	99	52	1.59
nozzle 4-2	11:16:22	36	89	177	100	53	1.58
nozzle 5-1	11:17:00	36	92	179	102	55	1.56
nozzle 5-2	11:17:39	36	92	178	101	54	1.55
Delavan d2s23 10bar	16/12/94						
nozzle 1-1	11:20:38	40	107	225	122	67	1.73
nozzle 1-2	11:21:16	40	106	228	121	65	1.78
nozzle 2-1	11:21:55	43	125	276	144	78	1.87
nozzle 2-2	11:22:33	43	125	280	145	77	1.90
nozzle 3-1	11:23:15	40	103	204	115	66	1.60
nozzle 3-2	11:23:53	39	103	205	115	65	1.62
nozzle 4-1	11:24:29	37	90	179	101	55	1.58
nozzle 4-2	11:25:10	37	91	178	101	56	1.56
nozzle 5-1	11:25:49	38	100	214	115	63	1.76
nozzle 5-2	11:27:27	39	101	217	117	66	1.76
Albuz 1299-10 10 bar	16/12/94						
nozzle 1-1	11:32:19	36	84	171	95	51	1.61
nozzle 1-2	11:33:02	35	84	168	94	50	1.57
nozzle 2-1	11:33:45	35	85	168	94	50	1.55
nozzle 2-2	11:34:25	35	83	164	90	46	1.55
nozzle 3-1	11:35:04	35	81	160	89	46	1.55
nozzle 3-2	11:35:44	35	80	159	89	46	1.55
nozzle 4-1	11:36:25	34	78	159	87	44	1.59
nozzle 4-2	11:37:04	34	78	157	87	44	1.59
nozzle 5-1	11:37:43	34	81	160	88	45	1.56
nozzle 5-2	11:39:09	34	81	161	88	45	1.58

Results	Time	0.1	VMD / 0.5	0.9	4,3	3,2	span
Lurmark d3s23 5 bar	16/12/94						
nozzle 1-1	13:15:13	49	108	218	124	82	1.57
nozzle 1-2	13:15:50	48	107	213	121	81	1.54
nozzle 2-1	13:17:05	48	111	213	123	83	1.48
nozzle 2-2	13:17:47	48	112	215	124	82	1.50
nozzle 3-1	13:18:27	43	99	186	109	72	1.43
nozzle 3-2	13:19:04	45	98	184	108	72	1.42
nozzle 4-1	13:19:43	44	100	192	111	74	1.48
nozzle 4-2	13:20:21	45	98	190	110	75	1.48
nozzle 5-1	13:21:00	45	107	208	119	77	1.51
nozzle 5-2	13:21:38	45	107	207	119	78	1.52
teejet d3s23 5 bar	16/12/94						
nozzle 1-1	13:25:32	43	101	191	111	72	1.46
nozzle 1-2	13:26:10	42	101	191	111	72	1.46
nozzle 2-1	13:27:27	41	101	192	111	69	1.50
nozzle 2-2	13:28:32	41	100	190	110	70	1.50
nozzle 3-1	13:29:16	43	105	195	115	74	1.45
nozzle 3-2	13:29:53	43	103	194	113	73	1.47
nozzle 4-1	13:30:32	42	103	191	112	72	1.45
nozzle 4-2	13:31:09	43	100	188	110	71	1.45
nozzle 5-1	13:31:46	43	106	199	116	74	1.47
nozzle 5-2	13:32:24	44	108	198	117	76	1.43
delavan d3s23 5 bar	16/12/94						
nozzle 1-1	13:44:54	49	117	241	134	86	1.64
nozzle 1-2	13:45:39	50	118	243	135	87	1.63
nozzle 2-1	13:46:24	47	119	241	134	85	1.63
nozzle 2-2	13:47:00	48	119	239	134	85	1.60
nozzle 3-1	13:47:38	50	129	255	144	93	1.59
nozzle 3-2	13:48:17	51	129	254	145	93	1.57
nozzle 4-1	13:50:30	45	110	209	121	77	1.50
nozzle 4-2	13:51:20	46	110	208	121	78	1.48
nozzle 5-1	13:52:35	50	129	272	147	91	1.73
nozzle 5-2	13:53:19	50	128	270	145	90	1.73

Lurmark d3s23 7bar	16/12/94						
nozzle 1-1	14:01:38	42	101	203	115	73	1.59
nozzle 1-2	14:02:15	41	97	196	111	71	1.59
nozzle 2-1	14:02:51	43	108	217	122	76	1.61
nozzle 2-2	14:03:33	43	108	216	122	76	1.62
nozzle 3-1	14:04:12	37	90	186	104	65	1.65
nozzle 3-2	14:04:51	37	91	189	105	66	1.66
nozzle 4-1	14:05:28	40	97	200	111	69	1.66
nozzle 4-2	14:06:09	39	97	201	112	69	1.67
nozzle 5-1	14:06:46	43	112	234	128	78	1.70
nozzle 5-2	14:07:27	43	114	231	129	79	1.65
teejet d3s23 7 bar	16/12/94						
nozzle 1-1	14:11:58	37	93	180	104	63	1.53
nozzle 1-2	14:12:40	37	94	180	104	62	1.52
nozzle 2-1	14:13:17	38	95	185	106	64	1.55
nozzle 2-2	14:13:53	38	95	187	107	64	1.56
nozzle 3-1	14:14:39	39	102	196	112	68	1.54
nozzle 3-2	14:15:16	39	102	195	112	68	1.52
nozzle 4-1	14:16:00	38	97	185	106	65	1.51
nozzle 4-2	14:16:39	38	97	184	106	64	1.50
nozzle 5-1	14:17:18	38	98	187	107	64	1.53
nozzle 5-2	14:17:56	38	98	186	107	63	1.52
Delavan d3s23 7bar	16/12/94						
nozzle 1-1	14:20:21	46	117	224	129	82	1.52
nozzle 1-2	14:20:57	46	117	224	128	81	1.52
nozzle 2-1	14:21:35	44	112	254	135	81	1.88
nozzle 2-2	14:22:19	44	108	242	129	78	1.84
nozzle 3-1	14:22:58	42	109	212	121	76	1.57
nozzle 3-2	14:23:36	42	107	208	119	75	1.56
nozzle 4-1	14:24:12	48	124	252	142	89	1.64
nozzle 4-2	14:24:55	48	124	242	137	87	1.57
nozzle 5-1	14:25:35	44	112	297	147	83	2.25
nozzle 5-2	14:26:12	44	110	292	145	81	2.26

Lurmark d3s23 10bar	16/12/94						
nozzle 1-1	14:33:17	36	91	192	105	63	1.71
nozzle 1-2	14:33:59	36	92	193	106	63	1.71
nozzle 2-1	14:34:36	39	105	220	120	72	1.72
nozzle 2-2	14:35:14	40	105	216	120	72	1.69
nozzle 3-1	14:35:51	35	89	176	100	61	1.57
nozzle 3-2	14:36:33	35	88	174	99	60	1.58
nozzle 4-1	14:37:13	36	89	190	105	63	1.72
nozzle 4-2	14:37:49	36	89	191	104	62	1.74
nozzle 5-1	14:38:33	38	96	203	112	67	1.72
nozzle 5-2	14:39:09	37	97	204	112	67	1.72
teejet d3s23 10 bar	16/12/94						
nozzle 1-1	14:42:19	35	93	176	102	63	1.52
nozzle 1-2	14:42:56	35	91	175	101	62	1.53
nozzle 2-1	14:43:31	37	97	185	106	67	1.53
nozzle 2-2	14:44:09	35	94	181	104	65	1.55
nozzle 3-1	14:44:50	35	94	179	103	64	1.52
nozzle 3-2	14:45:27	35	95	181	104	64	1.54
nozzle 4-1	14:46:06	35	92	175	101	61	1.52
nozzle 4-2	14:46:45	35	92	175	101	60	1.53
nozzle 5-1	14:47:21	35	94	177	103	62	1.51
nozzle 5-2	14:48:01	35	94	178	103	63	1.51
Delavan d3s23 10bar	16/12/94						
nozzle 1-1	14:54:51	40	101	213	117	71	1.71
nozzle 1-2	14:55:26	40	102	214	118	72	1.72
nozzle 2-1	14:56:02	40	104	242	127	75	1.94
nozzle 2-2	14:56:38	41	105	244	128	75	1.94
nozzle 3-1	14:58:30	37	94	200	110	69	1.72
nozzle 3-2	14:59:12	38	98	209	115	71	1.76
nozzle 4-1	14:59:53	42	110	222	124	78	1.64
nozzle 4-2	15:02:06	42	111	221	124	78	1.61
nozzle 5-1	15:02:43	38	97	244	123	70	2.12
nozzle 5-2	15:03:18	39	98	244	124	72	2.10

Results	Time	0.1	VMD / 0.5	0.9	4,3	3,2	span
Lurmark d2s25 5 bar	16/12/94						
nozzle 1-1	15:45:01	50	131	248	141	94	1.51
nozzle 1-2	15:45:41	50	131	253	143	93	1.55
nozzle 2-1	15:46:20	51	132	255	145	95	1.54
nozzle 2-2	15:46:56	50	131	253	143	93	1.55
nozzle 3-1	15:47:39	45	115	223	127	83	1.54
nozzle 3-2	15:48:19	44	114	223	126	82	1.58
nozzle 4-1	15:48:55	51	134	271	151	95	1.65
nozzle 4-2	15:49:37	51	133	270	151	95	1.64
nozzle 5-1	15:50:30	50	133	266	149	95	1.62
nozzle 5-2	15:51:14	51	133	268	150	95	1.64
teejet d2s25 5 bar	16/12/94						
nozzle 1-1	15:56:17	47	121	235	134	88	1.55
nozzle 1-2	15:56:54	47	120	232	133	86	1.55
nozzle 2-1	15:57:32	48	122	246	138	89	1.63
nozzle 2-2	15:58:07	47	121	232	133	87	1.53
nozzle 3-1	15:58:42	46	118	229	131	86	1.55
nozzle 3-2	15:59:18	45	117	228	130	84	1.56
nozzle 4-1	15:59:53	45	117	231	131	85	1.59
nozzle 4-2	16:00:30	46	117	230	130	84	1.58
nozzle 5-1	16:01:05	46	120	239	135	86	1.60
nozzle 5-2	16:01:39	47	123	244	137	88	1.60
delavan d2s25 5 bar	16/12/94						
nozzle 1-1	16:07:56	56	144	287	162	105	1.60
nozzle 1-2	16:08:32	57	146	290	164	106	1.60
nozzle 2-1	16:09:07	58	152	323	175	110	1.74
nozzle 2-2	16:09:43	58	151	314	172	110	1.70
nozzle 3-1	16:10:23	65	170	383	207	126	1.87
nozzle 3-2	16:11:03	64	173	392	211	125	1.89
nozzle 4-1	16:13:45	59	154	317	174	109	1.67
nozzle 4-2	16:14:20	59	152	313	172	109	1.67
nozzle 5-1	16:14:58	59	158	330	180	113	1.71
nozzle 5-2	16:15:34	60	161	352	190	116	1.81
Albuz 1299-12 5 bar	16/12/94						
nozzle 1-1	16:22:58	43.14	102.96	202.59	115.81	77.25	1.55
nozzle 1-2	16:23:41	42.81	101.83	201.43	115.13	75.74	1.56
nozzle 2-1	16:24:21	39.85	95.73	187.02	107.90	71.76	1.54
nozzle 2-2	16:24:59	41.03	95.52	186.73	107.88	71.91	1.53
nozzle 3-1	16:25:35	42.59	104.41	204.27	117.03	76.40	1.55
nozzle 3-2	16:26:10	42.35	105.15	203.02	117.23	77.22	1.53
nozzle 4-1	16:26:46	43.95	108.01	211.99	120.72	78.87	1.56
nozzle 4-2	16:27:22	42.88	106.57	211.07	119.99	78.01	1.58
nozzle 5-1	16:27:57	40.92	100.45	194.13	112.20	74.01	1.53
nozzle 5-2	16:28:32	41.18	99.58	192.86	111.52	72.85	1:52

Lumark d2s25 7bar	19/12/94						
nozzle 1-1	9:09:16	45.56	133.44	248.79	141.25	83.361	1.52
nozzle 1-2	9:09:57	43.97	128.97	243.42	137.23	79.67	1.55
nozzle 2-1	9:10:35	42.48	123.78	237.14	132.79	75.514	1.57
nozzle 2-2	9:11:15	42.19	123.02	236.28	132.29	74.399	1.58
nozzle 3-1	9:13:17	44.55	132.28	247.66	140.28	81.206	1.54
nozzle 3-2	9:13:57	44.68	132.58	250.11	140.72	81.718	1.55
nozzle 4-1	9:14:45	44.01	129.80	247.11	138.68	79.673	1.56
nozzle 4-2	9:15:25	43.00	126.61	242.16	135.40	76.684	1.57
nozzle 5-1	9:16:02	43.52	129.02	242.69	136.70	78.26	1.54
nozzle 5-2	9:16:45	42.89	126.69	240.48	135.05	76.775	1.56
teejet d2s25 7 bar	19/12/94						
nozzle 1-1	9:24:27	42.38	121.36	226.35	128.53	73.338	1.52
nozzle 1-2	9:25:17	42.33	122.23	234.82	131.38	72.69	1.57
nozzle 2-1	9:25:54	41.15	117.65	223.10	126.06	70.858	1.55
nozzle 2-2	9:26:32	41.36	119.38	224.89	127.40	71.393	1.54
nozzle 3-1	9:27:23	42.04	121.65	230.89	129.48	74.084	1.55
nozzle 3-2	9:28:27	41.97	122.24	228.93	130.38	73.622	1.53
nozzle 4-1	9:29:04	41.21	121.06	225.36	128.58	72.312	1.52
nozzle 4-2	9:29:43	41.70	121.05	227.53	128.57	73.443	1.54
nozzle 5-1	9:30:23	42.11	122.47	232.98	131.69	73.431	1.56
nozzle 5-2	9:31:56	42.35	123.50	237.33	133.09	73.834	1.58
Delavan d2s25 7bar	19/12/94						
nozzle 1-1	9:43:23	46.67	138.14	270.06	149.67	85.076	1.62
nozzle 1-2	9:44:01	44.91	136.91	269.62	148.47	81.772	1.64
nozzle 2-1	9:47:25	45.19	134.48	352.80	169.88	80.893	2.29
nozzle 2-2	9:48:07	46.30	138.33	356.17	172.52	83.085	2.24
nozzle 3-1	9:49:24	49.74	151.59	309.36	167.87	92.438	1.71
nozzle 3-2	9:50:00	50.00	153.63	316.81	170.38	94.842	1.74
nozzle 4-1	9:50:39	45.08	140.92	315.16	161.77	82.559	1.92
nozzle 4-2	9:52:02	45.95	144.07	312.98	162.98	84.37	1.85
nozzle 5-1	9:52:48	47.01	144.36	318.75	165.00	86.359	1.88
nozzle 5-2	9:53:43	47.05	147.05	317.88	166.01	87.48	1.84
Albuz 1299-12 7 bar	19/12/94						
nozzle 1-1	10:00:32	40.46	103.28	203.91	114.07	63.718	1.58
nozzle 1-2	10:01:13	40.43	104.90	204.95	115.50	65.06	1.57
nozzle 2-1	10:01:57	38.97	96.27	193.67	108.24	59.885	1.61
nozzle 2-2	10:02:37	39.32	94.13	190.40	106.04	58.074	1.60
nozzle 3-1	10:03:20	38.85	100.48	202.74	112.42	62.085	1.63
nozzle 3-2	10:04:27	39.58	97.61	200.95	111.20	60.99	1.65
nozzle 4-1	10:05:07	39.44	101.62	203.12	113.17	62.826	1.61
nozzle 4-2	10:05:44	39.82	102.64	203.45	113.99	64.28	1.59
nozzle 5-1	10:06:21	39.54	100.64	201.02	112.22	63.543	1.60
nozzle 5-2	10:07:00	40.43	100.85	199.86	112.45	64.695	1.58

Lurmark d2s25 10bar	19/12/94						
nozzle 1-1	10:33:44	40.38	123.75	234.30	131.67	70.35	1.57
nozzle 1-2	10:34:23	40.40	124.62	236.03	132.03	71.205	1.57
nozzle 2-1	10:35:00	40.68	127.09	242.16	135.35	71.992	1.59
nozzle 2-2	10:35:43	40.55	125.87	241.51	134.58	71.701	1.60
nozzle 3-1	10:37:09	40.76	126.36	235.15	133.10	72.156	1.54
nozzle 3-2	10:37:47	40.72	125.29	235.34	132.48	72.122	1.55
nozzle 4-1	10:38:26	39.88	124.06	234.82	132.20	70.714	1.57
nozzle 4-2	10:39:04	39.87	123.51	236.96	132.84	71.953	1.60
nozzle 5-1	10:39:44	40.01	125.82	240.38	133.99	71.152	1.59
nozzle 5-2	10:40:21	40.27	126.61	240.37	134.94	72.181	1.58
teejet d2s25 10 bar	19/12/94						
nozzle 1-1	10:44:04	37.87	113.19	211.92	120.45	64.446	1.54
nozzle 1-2	10:44:41	38.07	114.77	214.67	121.77	65.341	1.54
nozzle 2-1	10:45:22	38.42	116.45	216.91	123.14	66.621	1.53
nozzle 2-2	10:46:01	37.69	113.34	212.32	120.82	64.184	1.54
nozzle 3-1	10:46:40	37.14	112.07	210.34	119.31	63.297	1.55
nozzle 3-2	10:47:17	37.64	113.59	214.00	120.85	64.63	1.55
nozzle 4-1	10:47:56	37.59	114.39	213.66	121.67	65.806	1.54
nozzle 4-2	10:48:32	37.99	115.40	216.64	123.23	66.284	1.55
nozzle 5-1	10:49:11	38.11	117.88	219.81	124.88	66.979	1.54
nozzle 5-2	10:49:54	38.40	116.75	221.55	124.94	67.154	1.57
Delavan d2s25 10bar	19/12/94						
nozzle 1-1	11:04:37	42.36	128.92	268.07	144.01	80.124	1.75
nozzle 1-2	11:05:26	42.98	129.37	279.27	148.91	83.281	1.83
nozzle 2-1	11:07:11	41.73	123.66	258.62	139.36	77.195	1.75
nozzle 2-2	11:07:51	41.62	123.76	258.08	138.96	76.86	1.75
nozzle 3-1	11:08:42	39.83	120.63	251.01	135.32	73.451	1.75
nozzle 3-2	11:10:08	41.60	122.35	261.41	141.02	80.844	1.80
nozzle 4-1	11:10:45	41.53	124.01	275.67	145.71	81.245	1.89
nozzle 4-2	11:11:21	42.48	124.64	275.59	146.34	82.417	1.87
nozzle 5-1	11:11:58	44.20	131.62	309.34	157.52	83.426	2.01
nozzle 5-2	11:12:35	45.80	136.00	321.83	166.83	90.721	2.03
Albuz 1299-12 10 bar	19/12/94						
nozzle 1-1	11:16:26	36.07	101.84	197.59	111.13	59.808	1.59
nozzle 1-2	11:17:07	35.87	100.64	196.16	110.29	58.936	1.59
nozzle 2-1	11:20:11	35.46	99.24	190.93	108.21	58.712	1.57
nozzle 2-2	11:21:32	35.38	98.17	190.35	107.58	58.492	1.58
nozzle 3-1	11:22:14	36.01	103.94	203.22	113.91	61.784	1.61
nozzle 3-2	11:22:50	35.77	101.60	200.92	112.22	59.824	1.63
nozzle 4-1	11:24:06	35.03	99.92	196.94	109.61	58.372	1.62
nozzle 4-2	11:24:42	35.24	99.66	196.13	109.68	58.584	1.61
nozzle 5-1	11:25:22	35.11	97.82	190.78	106.96	56.435	1.59
nozzle 5-2	11:26:00	35.38	98.03	191.32	107.41	57.504	1.59

Results	Time	0.1	VMD / 0.5	0.9	4,3	3,2	span
Lurmark d3s25 5 bar	19-Dec						
nozzle 1-1	16:17:05	56.46	150.91	303.93	170.70	106.881	1.64
nozzle 1-2	16:17:49	57.35	151.84	293.56	166.60	105.76	1.56
nozzle 2-1	16:18:23	53.67	142.85	281.05	159.12	100.488	1.59
nozzle 2-2	16:18:59	53.21	141.10	278.62	158.05	98.987	1.60
nozzle 3-1	16:19:36	52.90	140.05	264.21	151.85	97.119	1.51
nozzle 3-2	16:20:13	52.43	139.64	264.81	151.34	96.523	1.52
nozzle 4-1	16:20:47	52.34	139.08	274.32	155.09	97.741	1.60
nozzle 4-2	16:21:21	51.64	138.09	274.44	154.49	95.845	1.61
nozzle 5-1	16:21:54	53.44	145.65	290.70	163.46	100.7	1.63
nozzle 5-2	16:22:29	53.97	146.89	277.60	158.61	99.47	1.52
teejet d3s25 5 bar	19-Dec						
nozzle 1-1	16:25:27	48.01	127.52	252.75	142.75	89.562	1.61
nozzle 1-2	16:26:05	45.66	122.73	237.61	134.68	83.537	1.56
nozzle 2-1	16:26:44	48.02	126.90	254.51	143.08	89.569	1.63
nozzle 2-2	16:27:19	47.27	126.76	247.09	139.09	87.293	1.58
nozzle 3-1	16:27:52	46.98	125.63	248.48	140.37	87.502	1.60
nozzle 3-2	16:28:28	47.24	126.29	238.14	136.88	86.581	1.51
nozzle 4-1	16:29:04	46.18	123.10	234.81	134.31	84.253	1.53
nozzle 4-2	16:29:38	46.66	124.85	235.90	135.35	85.796	1.52
nozzle 5-1	16:30:14	46.70	126.17	235.32	135.80	86.58	1.49
nozzle 5-2	16:30:48	46.41	124.54	234.98	135.00	84.259	1.51
Albuz 1299-14 5 bar	19-Dec						
nozzle 1-1	16:33:07	44.67	111.24	212.73	122.38	78.587	1.51
nozzle 1-2	16:34:07	45.55	112.33	214.01	123.73	79.627	1.50
nozzle 2-1	16:36:03	43.08	108.49	209.25	119.99	76.327	1.53
nozzle 2-2	16:36:41	43.24	105.97	205.26	118.13	75.728	1.53
nozzle 3-1	16:37:19	44.34	114.33	220.88	126.23	79.866	1.54
nozzle 3-2	16:37:57	44.23	110.34	218.85	123.53	77.642	1.58
nozzle 4-1	16:38:34	42.69	108.86	211.82	120.69	-74.711	1.55
nozzle 4-2	16:39:09	42.57	110.62	211.33	121.49	75.266	1.53
nozzle 5-1	16:39:47	43.84	114.91	222.58	126.88	78.242	1.56
nozzle 5-2	16:40:24	44.12	114.44	225.06	127.11	78.163	1.58

Lurmark d3s25 7bar	20-Dec						
nozzle 1-1	8:48:49	50.53	145.34	288.22	160.92	95.564	1.64
nozzle 1-2	8:50:06	51.41	146.83	288.06	161.59	96.824	1.61
nozzle 2-1	8:50:43	49.47	139.80	265.44	150.42	92.89	1.54
nozzle 2-2	8:51:21	49.04	140.10	271.48	153.24	91.531	1.59
nozzle 3-1	8:51:58	48.85	139.03	262.73	148.91	91.584	1.54
nozzle 3-2	8:52:36	48.80	139.35	271.69	151.84	90.585	1.60
nozzle 4-1	8:53:13	48.00	138.36	259.78	148.07	90.354	1.53
nozzle 4-2	8:54:04	49.18	137.61	256.92	146.16	93.034	1.51
nozzle 5-1	8:54:39	47.99	135.11	251.90	143.51	91.467	1.51
nozzle 5-2	8:55:23	48.43	135.79	255.43	145.11	92.079	1.52
teejet d3s25 7 bar	20-Dec						
nozzle 1-1	8:39:09	46.65	128.27	243.22	136.81	88.137	1.53
nozzle 1-2	8:39:46	46.64	126.33	236.57	135.05	87.768	1.50
nozzle 2-1	8:40:25	45.48	123.67	233.74	132.96	85.249	1.52
nozzle 2-2	8:41:02	44.83	119.59	233.21	131.02	83.574	1.58
nozzle 3-1	8:41:40	44.68	119.86	226.80	130.00	82.933	1.52
nozzle 3-2	8:42:16	44.78	121.65	228.66	131.50	83.925	1.51
nozzle 4-1	8:42:55	44.31	120.60	233.01	131.50	83.042	1.56
nozzle 4-2	8:43:32	44.49	121.08	234.97	132.32	82.773	1.57
nozzle 5-1	8:44:08	44.89	123.75	230.07	132.04	83.877	1.50
nozzle 5-2	8:44:44	45.14	123.46	230.11	132.94	83.293	1.50
Albuz 1299-14 7 bar	20-Dec						
nozzle 1-1	8:58:09	44.31	107.41	217.85	122.12	81.682	1.62
nozzle 1-2	8:58:51	44.43	107.91	216.00	121.76	81.764	1.59
nozzle 2-1	8:59:31	41.05	100.11	204.51	115.26	77.065	1.63
nozzle 2-2	9:00:16	41.89	99.78	205.04	115.91	77.721	1.64
nozzle 3-1	9:00:59	42.87	109.72	218.99	121.79	80.735	1.61
nozzle 3-2	9:01:42	42.83	109.34	216.04	122.16	77.342	1.58
nozzle 4-1	9:02:25	41.91	107.53	211.48	120.02	77.833	1.58
nozzle 4-2	9:03:07	42.45	105.81	210.08	119.21	79.152	1.58
nozzle 5-1	9:08:24	44.95	121.39	234.60	131.13	84.568	1.56
nozzle 5-2	9:09:17	45.50	116.88	230.09	129.12	83.796	1.58

Lurmark d3s25 10bar	20-Dec						
nozzle 1-1	9:13:13	47.32	136.80	270.83	148.82	89.966	1.63
nozzle 1-2	9:14:04	48.40	142.01	280.83	155.58	91.519	1.64
nozzle 2-1	9:15:01	46.45	132.37	252.49	142.21	88.911	1.56
nozzle 2-2	9:15:40	46.75	136.16	259.28	145.40	89.164	1.56
nozzle 3-1	9:16:21	47.00	134.91	255.57	143.33	89.775	1.55
nozzle 3-2	9:17:00	47.14	134.97	255.84	143.80	90.16	1.55
nozzle 4-1	9:17:44	46.89	138.14	267.47	148.62	89.383	1.60
nozzle 4-2	9:18:23	48.47	141.86	273.74	152.09	92.471	1.59
nozzle 5-1	9:19:38	45.61	137.26	281.31	167.58	84.881	1.72
nozzle 5-2	9:20:28	45.88	134.10	251.66	142.65	85.697	1.53
teejet d3s25 10 bar							
nozzle 1-1	9:29:48	43.082	124.692	230.227	131.115	83.869	1.50
nozzle 1-2	9:30:31	42.938	122.649	227.198	130.346	80.655	1.50
nozzle 2-1	9:31:08	40.501	114.648	226.034	125.855	72.691	1.62
nozzle 2-2	9:31:48	41.525	115.643	221.718	125.555	78.917	1.56
nozzle 3-1	9:32:28	41.798	117.978	216.151	125.138	80.947	1.48
nozzle 3-2	9:33:06	42.513	120.249	220.282	127.757	82	1.48
nozzle 4-1	9:33:50	41.215	114.798	215.94	122.854	76.508	1.52
nozzle 4-2	9:34:30	41.355	116.314	217.62	124.183	80.75	1.52
nozzle 5-1	9:35:09	42.765	123.984	227.613	129.438	82.293	1.49
nozzle 5-2	9:35:50	43.674	126.152	231.637	132.066	85.02	1.49
Albuz 1299-14 10 bar							
nozzle 1-1	9:41:54	39.614	104.903	211.753	117.522	67.808	1.64
nozzle 1-2	9:42:39	39.035	101.884	209.763	115.991	66.411	1.68
nozzle 2-1	9:43:52	39.588	104.609	211.248	117.298	68.048	1.64
nozzle 2-2	9:44:44	39.702	104.101	211.68	117.158	68.608	1.65
nozzle 3-1	9:45:32	39.496	106.262	216.479	119.331	68.983	1.67
nozzle 3-2	9:46:13	40.483	108.416	212.491	119.899	75.414	1.59
nozzle 4-1	9:46:49	39.55	106.024	211.116	117.623	69.307	1.62
nozzle 4-2	9:47:29	40.228	106.604	208.923	118.064	75.575	1.58
nozzle 5-1	9:48:05	43.2926	113.406	222.976	125.497	80.806	1.58
nozzle 5-2	9:49:12	41.393	110.208	220.505	123.273	78.249	1.63

Results	**Time**	**0.1**	**VMD / 0.5**	**0.9**	**4,3**	**3,2**	**span**
Lurmark d3s45 5 bar	20-Dec						
nozzle 1-1	10:43:26	60.33	179.39	331.16	192.09	113.681	1.51
nozzle 1-2	10:44:01	59.68	178.15	332.06	191.41	112.073	1.53
nozzle 2-1	10:44:42	57.13	171.22	319.42	183.50	107.894	1.53
nozzle 2-2	10:45:16	57.45	170.83	320.22	183.85	107.911	1.54
nozzle 3-1	10:45:55	56.35	174.07	320.53	182.57	100.814	1.52
nozzle 3-2	10:46:32	58.44	174.49	322.81	185.74	106.451	1.52
nozzle 4-1	10:47:07	56.86	173.10	324.83	186.13	107.84	1.55
nozzle 4-2	10:47:42	57.74	174.56	326.86	188.48	109.91	1.54
nozzle 5-1	10:48:19	59.05	175.69	325.32	188.73	110.994	1.52
nozzle 5-2	10:49:05	58.90	177.95	333.00	190.46	110.394	1.54
teejet d3s45 5 bar	20-Dec						
nozzle 1-1	10:51:30	54.59	174.10	331.95	186.78	105.08	1.59
nozzle 1-2	10:52:05	55.19	174.48	329.37	186.56	105.502	1.57
nozzle 2-1	10:52:40	55.89	177.84	326.85	188.92	106.827	1.52
nozzle 2-2	10:53:16	55.19	175.19	336.97	188.81	105.856	1.61
nozzle 3-1	10:53:52	52.12	169.13	327.34	182.69	101.345	1.63
nozzle 3-2	10:54:27	54.39	172.50	330.29	186.25	104.236	1.60
nozzle 4-1	10:55:03	52.62	170.14	319.72	181.73	101.109	1.57
nozzle 4-2	10:55:38	53.87	170.92	327.17	184.18	103.979	1.60
nozzle 5-1	10:56:13	55.48	176.72	331.73	188.93	107.603	1.56
nozzle 5-2	10:56:49	55.77	177.78	338.79	191.32	109.114	1.59
delavan d3s45 5 bar	20-Dec						
Albuz 1299-16 5 bar	20-Dec						
nozzle 1-1	11:00:00	49.85	140.51	275.24	152.75	90.025	1.60
nozzle 1-2	11:00:45	50.26	141.23	281.32	153.60	90.045	1.64
nozzle 2-1	11:01:25	48.19	138.50	278.01	151.22	66.504	1.66
nozzle 2-2	11:02:04	49.70	136.18	270.93	148.26	89.039	1.62
nozzle 3-1	11:03:02	48.79	142.59	281.86	154.90	88.969	1.63
nozzle 3-2	11:03:43	49.33	142.26	278.50	154.65	89.003	1.61
nozzle 4-1	11:04:26	49.40	141.67	283.01	155.05	88.631	1.65
nozzle 4-2	11:05:16	49.58	143.74	282.85	156.04	89.407	1.62
nozzle 5-1	11:05:57	49.29	141.70	279.00	154.48	88	1.62
nozzle 5-2	11:06:50	49.83	146.36	289.28	158.49	90.544	1.64
Lurmark d3s45 7bar	20-Dec						
nozzle 1-1	11:12:59	58.56	169.10	311.57	180.41	107.82	1.50

nozzle 1-2	11:14:50	55.88	165.99	306.07	178.26	103.943	1.51
nozzle 2-1	11:16:39	54.44	161.47	298.38	171.40	98.741	1.51
nozzle 2-2	11:17:18	57.21	166.41	310.15	178.47	105.103	1.52
nozzle 3-1	11:17:56	54.74	162.63	298.99	173.62	100.633	1.50
nozzle 3-2	11:18:35	55.00	165.19	311.69	177.60	102.184	1.55
nozzle 4-1	11:19:10	55.88	163.70	305.84	174.72	102.595	1.53
nozzle 4-2	11:19:46	57.16	167.98	311.42	178.05	104.66	1.51
nozzle 5-1	11:20:22	56.48	165.45	304.76	175.84	103.118	1.50
nozzle 5-2	11:20:56	57.49	168.71	309.16	179.49	105.665	1.49
teejet d3s45 7 bar	20-Dec						
nozzle 1-1	11:36:17	50.91	159.43	297.27	169.31	95.007	1.55
nozzle 1-2	11:36:50	53.47	164.18	314.96	179.43	102.69	1.59
nozzle 2-1	11:37:26	52.16	161.15	297.90	170.92	97.248	1.52
nozzle 2-2	11:38:00	53.67	165.71	318.28	181.02	103.152	1.60
nozzle 3-1	11:38:37	51.91	159.84	310.20	175.82	100.064	1.62
nozzle 3-2	11:39:13	51.24	160.94	300.63	170.71	96.571	1.55
nozzle 4-1	11:39:51	53.22	165.16	317.67	182.26	103.574	1.60
nozzle 4-2	11:41:05	53.78	167.72	310.76	177.64	101.116	1.53
nozzle 5-1	11:42:37	50.68	158.02	294.30	167.72	95.24	1.54
nozzle 5-2	11:43:17	51.50	159.52	293.88	168.71	96.764	1.52
Albuz 1299-16 7 bar	20-Dec						
nozzle 1-1	11:47:19	45.30	136.70	268.70	148.21	82.065	1.63
nozzle 1-2	11:48:11	46.65	139.15	268.43	150.08	85.181	1.59
nozzle 2-1	11:49:05	45.86	136.96	270.01	148.54	82.021	1.64
nozzle 2-2	11:49:41	45.69	136.83	268.00	148.05	81.68	1.62
nozzle 3-1	11:50:19	46.41	145.42	278.67	155.39	84.969	1.60
nozzle 3-2	11:50:57	47.30	146.19	283.26	156.74	86.615	1.61
nozzle 4-1	11:51:38	46.03	140.94	277.84	152.10	83.738	1.64
nozzle 4-2	11:52:19	46.18	140.21	275.95	151.87	82.977	1.64
nozzle 5-1	11:52:54	46.70	144.21	278.18	154.49	85.043	1.61
nozzle 5-2	11:53:31	46.72	144.31	282.20	155.52	85.524	1.63

Lurmark d3s45 10bar	20-Dec						
nozzle 1-1	13:12:00	57.29	158.42	314.02	179.69	105.716	1.62
nozzle 1-2	13:13:06	56.75	157.28	294.91	169.89	102.105	1.51
nozzle 2-1	13:14:20	52.32	150.50	300.42	167.91	96.525	1.65
nozzle 2-2	13:14:55	54.93	154.27	297.25	167.46	99.72	1.57
nozzle 3-1	13:16:00	54.57	152.35	285.28	163.28	98.434	1.51
nozzle 3-2	13:16:36	56.46	155.74	288.55	166.51	101.129	1.49
nozzle 4-1	13:17:23	51.02	147.57	291.71	164.59	95.564	1.63
nozzle 4-2	13:17:57	52.51	150.71	299.25	167.80	97.713	1.64
nozzle 5-1	13:18:34	56.05	154.45	307.51	173.34	101.701	1.63
nozzle 5-2	13:19:10	58.11	158.08	298.49	170.39	102.82	1.52
teejet d3s45 10 bar	20-Dec						
nozzle 1-1	13:22:48	51.55	153.80	303.81	170.95	96.948	1.64
nozzle 1-2	13:23:29	52.76	154.96	305.04	171.95	99.042	1.63
nozzle 2-1	13:24:46	51.64	151.81	298.14	168.66	96.974	1.62
nozzle 2-2	13:25:20	49.02	147.77	293.65	164.82	92.872	1.66
nozzle 3-1	13:25:55	50.95	151.45	297.35	167.84	95.441	1.63
nozzle 3-2	13:26:32	50.58	150.55	297.54	167.32	95.343	1.64
nozzle 4-1	13:27:06	48.05	145.82	287.67	161.27	90.842	1.64
nozzle 4-2	13:27:42	49.96	149.37	291.82	164.63	94.266	1.62
nozzle 5-1	13:28:17	47.16	143.11	280.36	157.45	89.307	1.63
nozzle 5-2	13:28:50	49.05	146.70	287.69	162.11	92.68	1.63
Albuz 1299-16 10 bar	20-Dec						
nozzle 1-1	13:36:48	44.02	131.51	267.50	145.42	82.108	1.70
nozzle 1-2	13:37:26	42.18	128.28	265.76	144.05	79.772	1.74
nozzle 2-1	13:38:04	41.54	129.04	262.05	143.38	78.73	1.71
nozzle 2-2	13:38:45	42.63	131.14	262.10	144.58	80.723	1.67
nozzle 3-1	13:39:25	45.39	136.19	280.33	153.78	85.818	1.73
nozzle 3-2	13:39:59	45.41	136.68	281.00	155.01	86.404	1.72
nozzle 4-1	13:40:36	44.30	135.04	281.37	155.06	84.888	1.76
nozzle 4-2	13:41:23	45.04	135.85	277.58	152.87	85.742	1.71
nozzle 5-1	13:46:23	47.67	132.01	261.61	144.58	85.867	1.62
nozzle 5-2	13:47:02	48.41	133.33	262.98	145.80	87.094	1.61

Results	**Time**	**0.1**	**VMD / 0.5**	**0.9**	**4,3**	**3,2**	**span**
Spray Sys TX 3C 5 bar	20-Dec						
nozzle 1-1	14:29:12	38.36	65.52	121.02	72.94	48.931	1.26
nozzle 1-2	14:30:10	37.31	65.56	121.47	72.46	47.923	1.28
nozzle 2-1	14:30:52	38.62	65.91	123.67	73.67	48.843	1.29
nozzle 2-2	14:31:32	39.01	65.84	121.80	73.49	49.864	1.26
nozzle 3-1	14:32:12	36.66	64.32	121.67	72.00	47.554	1.32
nozzle 3-2	14:32:52	37.03	64.85	121.55	72.28	48.569	1.30
nozzle 4-1	14:33:32	36.78	64.83	116.67	71.16	49.486	1.23
nozzle 4-2	14:34:16	37.62	64.27	114.29	70.55	48.315	1.19
nozzle 5-1	14:34:57	36.88	64.74	115.69	70.71	49.18	1.22
nozzle 5-2	14:35:36	36.06	64.34	115.53	70.49	49.734	1.24
Spray Sys TX 4C 5 bar	20-Dec						
nozzle 1-1	14:42:41	39.46	73.10	141.22	82.39	54.391	1.39
nozzle 1-2	14:43:20	38.99	73.42	140.21	82.16	53.692	1.38
nozzle 2-1	14:44:07	38.83	70.99	130.95	78.69	54.033	1.30
nozzle 2-2	14:45:47	38.75	71.73	132.92	79.73	53.898	1.31
nozzle 3-1	14:46:26	38.54	71.46	134.99	80.07	52.866	1.35
nozzle 3-2	14:47:05	38.81	71.78	135.03	79.89	52.293	1.34
nozzle 4-1	14:47:48	38.88	71.91	141.34	81.19	51.823	1.42
nozzle 4-2	14:48:27	38.24	71.33	140.00	80.93	51.71	1.43
nozzle 5-1	14:49:06	37.71	70.30	133.65	78.80	51.914	1.36
nozzle 5-2	14:49:43	37.41	69.81	132.23	78.41	51.943	1.36
Spray Sys TX 6C 5 bar	20-Dec						
nozzle 1-1	14:53:19	40.42	81.89	160.46	92.49	57.616	1.47
nozzle 1-2	14:53:58	39.63	81.13	159.23	91.15	55.69	1.47
nozzle 2-1	14:54:43	39.55	78.80	155.30	88.84	55.804	1.47
nozzle 2-2	14:55:22	39.69	78.67	154.59	89.09	56.377	1.46
nozzle 3-1	14:56:01	39.36	76.95	153.64	87.83	56.406	1.49
nozzle 3-2	14:56:39	39.51	79.25	155.11	90.02	57.067	1.46
nozzle 4-1	14:57:17	38.90	78.91	156.06	88.95	54.975	1.48
nozzle 4-2	14:57:57	39.43	80.36	153.61	88.92	54.364	1.42
nozzle 5-1	14:59:36	38.68	78.29	157.04	88.86	53.385	1.51
nozzle 5-2	15:00:16	39.61	76.23	155.25	87.80	56.13	1.52
Spray Sys TX 10C 5 bar	20-Dec						
nozzle 1-1	15:04:59	42.56	94.26	193.12	109.00	67.403	1.60
nozzle 1-2	15:05:52	41.82	92.05	189.83	107.08	66.2	1.61
nozzle 2-1	15:06:36	40.68	91.49	183.68	104.41	64.164	1.56
nozzle 2-2	15:07:19	41.97	90.87	183.00	104.95	66.43	1.55
nozzle 3-1	15:08:14	41.88	96.20	190.26	108.41	67.485	1.54
nozzle 3-2	15:08:53	42.26	95.33	192.84	109.23	67.96	1.58
nozzle 4-1	15:09:34	42.73	96.77	191.59	108.83	70.999	1.54
nozzle 4-2	15:10:14	42.17	95.08	190.62	108.05	69.239	1.56
nozzle 5-1	15:10:59	42.66	94.56	186.76	106.80	70.778	1.52
nozzle 5-2	15:11:39	42.13	93.68	188.29	106.48	68.174	1.56

Spray Sys TX 3C 7 bar	21-Dec						
nozzle 1-1	8:21:08	33.38	68.07	120.28	73.89	54.898	1.28
nozzle 1-2	8:21:50	32.94	67.16	119.25	73.03	53.237	1.29
nozzle 2-1	8:22:30	33.12	66.93	121.50	73.54	53.711	1.32
nozzle 2-2	8:23:06	32.69	67.32	121.88	73.48	53.525	1.32
nozzle 3-1	8:26:17	31.91	65.82	118.93	72.15	53.166	1.32
nozzle 3-2	8:27:02	32.17	66.87	119.05	72.39	53.152	1.30
nozzle 4-1	8:27:39	32.22	64.32	113.80	69.76	51.19	1.27
nozzle 4-2	8:28:17	32.69	65.74	115.94	71.52	52.505	1.27
nozzle 5-1	8:28:52	34.15	73.08	125.84	78.05	56.867	1.25
nozzle 5-2	8:29:36	32.23	64.85	113.57	69.91	51.37	1.25
Spray Sys TX 4C 7 bar	21/12/94						
nozzle 1-1	8:32:49	34.04	73.91	134.19	80.77	54.714	1.36
nozzle 1-2	8:33:31	34.50	74.96	134.64	81.02	54.006	1.34
nozzle 2-1	8:34:13	33.63	70.49	126.59	76.12	49.843	1.32
nozzle 2-2	8:34:55	33.86	71.65	128.08	77.08	51.341	1.31
nozzle 3-1	8:35:35	33.41	72.42	132.82	78.48	51.688	1.37
nozzle 3-2	8:36:22	33.66	71.66	128.92	77.92	52.22	1.33
nozzle 4-1	8:37:21	33.37	71.38	132.61	77.98	49.64	1.39
nozzle 4-2	8:38:17	33.45	71.62	132.30	78.59	51.087	1.38
nozzle 5-1	8:39:49	33.43	72.19	129.95	78.05	50.791	1.34
nozzle 5-2	8:40:48	33.33	72.31	130.72	77.87	50.07	1.35
Spray Sys TX 6C 7 bar	21/12/94						
nozzle 1-1	8:43:51	34.75	83.69	156.53	91.76	61.635	1.46
nozzle 1-2	8:44:29	34.26	84.31	157.37	92.40	61.971	1.46
nozzle 2-1	8:45:11	33.72	79.26	150.68	88.03	58.112	1.48
nozzle 2-2	8:45:48	34.19	81.85	154.58	90.58	61.726	1.47
nozzle 3-1	8:46:36	33.86	79.02	149.91	87.83	58.913	1.47
nozzle 3-2	8:47:33	34.50	82.56	156.13	91.53	62.84	1.47
nozzle 4-1	8:48:13	33.51	83.29	158.00	91.83	61.313	1.49
nozzle 4-2	8:48:55	34.49	83.72	158.55	92.24	61.377	1.48
nozzle 5-1	8:50:30	34.30	84.65	160.44	93.52	62.497	1.49
nozzle 5-2	8:51:07	34.61	84.09	159.70	93.09	62.197	1.49
Spray Sys TX 10C 7 bar	21/12/94						
nozzle 1-1	8:55:28	38.65	105.03	204.01	115.68	74.162	1.57
nozzle 1-2	8:56:06	38.74	104.72	199.89	114.73	74.273	1.54
nozzle 2-1	8:56:45	37.72	103.28	196.19	112.88	72.411	1.53
nozzle 2-2	8:57:24	37.68	100.35	192.73	110.84	71.494	1.55
nozzle 3-1	8:58:03	37.97	104.44	202.01	115.13	73.86	1.57
nozzle 3-2	8:58:39	38.10	104.24	201.62	114.75	73.463	1.57
nozzle 4-1	8:59:17	38.19	104.95	203.07	115.46	73.334	1.57
nozzle 4-2	9:00:57	37.69	105.98	203.42	116.02	74.16	1.56
nozzle 5-1	9:01:43	37.78	104.03	198.27	113.60	72.457	1.54
nozzle 5-2	9:02:21	38.31	104.55	200.76	114.77	74.157	1.55

Spray Sys TX 3C 10 bar	21/12/94						
nozzle 1-1	9:11:55	31.74	63.21	115.07	69.63	49.862	1.32
nozzle 1-2	9:14:35	31.05	65.24	114.61	69.93	50.769	1.28
nozzle 2-1	9:15:32	30.82	64.75	118.11	70.62	51.692	1.35
nozzle 2-2	9:16:09	30.61	63.97	117.18	69.83	50.952	1.35
nozzle 3-1	9:16:48	30.78	63.08	113.25	68.61	50.617	1.31
nozzle 3-2	9:17:23	30.84	63.81	115.50	69.46	51.624	1.33
nozzle 4-1	9:18:16	30.46	61.91	107.42	65.88	49.971	1.24
nozzle 4-2	9:18:54	30.01	61.06	106.83	65.61	49.235	1.26
nozzle 5-1	9:19:34	29.82	59.94	103.33	64.17	48.458	1.23
nozzle 5-2	9:20:13	30.38	60.60	102.88	64.28	48.946	1.20
Spray Sys TX 4C 10 bar	21/12/94						
nozzle 1-1	9:22:44	32.27	70.11	127.14	75.16	50.494	1.35
nozzle 1-2	9:23:31	31.72	68.68	125.38	73.93	50.746	1.36
nozzle 2-1	9:24:11	30.73	65.62	116.89	69.95	50.617	1.31
nozzle 2-2	9:24:55	31.65	67.33	120.71	71.82	49.046	1.32
nozzle 3-1	9:25:35	31.33	68.09	123.18	73.07	48.188	1.35
nozzle 3-2	9:26:12	31.31	69.40	124.51	74.76	53.162	1.34
nozzle 4-1	9:26:54	30.94	69.00	125.96	73.69	47.746	1.38
nozzle 4-2	9:27:51	30.01	68.68	125.03	74.56	54.293	1.38
nozzle 5-1	9:29:21	31.07	67.54	122.46	72.82	50.683	1.35
nozzle 5-2	9:30:01	31.18	68.22	124.36	73.59	51.242	1.37
Spray Sys TX 6C 10 bar	21-Dec						
nozzle 1-1	9:33:55	32.32	79.67	153.22	88.18	61.409	1.52
nozzle 1-2	9:34:36	31.59	79.99	152.14	88.09	60.792	1.51
nozzle 2-1	9:35:15	31.72	78.14	149.62	86.44	59.871	1.51
nozzle 2-2	9:36:03	31.57	78.20	149.34	86.16	59.638	1.51
nozzle 3-1	9:36:46	31.07	78.13	150.40	86.51	59.913	1.53
nozzle 3-2	9:37:28	31.33	78.93	149.77	87.04	61.014	1.50
nozzle 4-1	9:38:10	31.22	80.74	154.85	88.95	61.111	1.53
nozzle 4-2	9:38:49	31.68	80.19	154.07	88.58	61.103	1.53
nozzle 5-1	9:39:29	31.26	81.38	155.49	89.53	61.304	1.53
nozzle 5-2	9:40:07	31.25	80.30	154.47	88.61	59.859	1.53
Spray Sys TX 10C 10 bar	21/12/94						
nozzle 1-1	9:44:20	36.08	100.51	190.82	111.18	75.239	1.54
nozzle 1-2	9:44:59	36.53	102.18	193.95	112.06	74.854	1.54
nozzle 2-1	9:45:38	35.35	98.20	188.72	108.68	73.502	1.56
nozzle 2-2	9:46:16	34.59	98.47	187.72	108.75	74.147	1.56
nozzle 3-1	9:46:53	35.61	102.51	195.28	113.06	75.938	1.56
nozzle 3-2	9:48:16	36.13	102.93	195.93	113.28	76.071	1.55
nozzle 4-1	9:48:53	35.76	103.69	195.47	113.41	76.244	1.54
nozzle 4-2	9:49:30	35.07	102.65	193.08	112.30	75.186	1.54
nozzle 5-1	9:50:08	34.64	99.56	188.63	109.47	73.68	1.55
nozzle 5-2	9:50:44	35.98	100.26	193.22	110.56	71.582	1.57

Results	Time	0.1	VMD / 0.5	0.9	4,3	3,2	span
Spray Sys TX 2B 5 bar	21-Dec						
nozzle 1-1	16:00:20	36.40	65.59	118.38	72.73	50.775	1.25
nozzle 1-2	16:01:07	37.74	65.77	116.93	71.67	47.681	1.20
nozzle 2-1	16:01:43	36.49	66.90	121.48	74.27	52.306	1.27
nozzle 2-2	16:02:27	37.18	66.68	118.57	73.64	52.307	1.22
nozzle 3-1	16:03:06	38.50	65.25	118.83	71.90	46.598	1.23
nozzle 3-2	16:03:41	38.18	68.49	122.65	75.74	52.634	1.23
nozzle 4-1	16:04:27	37.12	65.93	119.83	72.28	45.971	1.25
nozzle 4-2	16:05:08	38.51	64.67	117.53	71.45	47.484	1.22
nozzle 5-1	16:05:45	37.95	65.72	111.97	71.33	51.539	1.13
nozzle 5-2	16:06:20	38.66	66.64	111.74	72.15	55.012	1.10
Spray Sys TX 3B 5 bar	21-Dec						
nozzle 1-1	16:07:37	39.19	69.81	128.84	77.52	49.664	1.28
nozzle 1-2	16:10:53	38.24	68.93	126.68	76.38	49.2	1.28
nozzle 2-1	16:12:11	38.00	67.42	128.97	76.45	47.709	1.35
nozzle 2-2	16:12:53	37.58	66.09	128.42	75.23	47.785	1.37
nozzle 3-1	16:13:33	38.69	68.13	124.77	75.42	48.439	1.26
nozzle 3-2	16:14:40	39.23	71.27	127.95	78.20	49.771	1.24
nozzle 4-1	16:15:20	39.60	70.97	131.67	79.08	49.842	1.30
nozzle 4-2	16:17:45	38.91	70.25	132.24	78.79	50.049	1.33
nozzle 5-1	16:19:10	38.83	71.96	131.86	78.43	48.524	1.29
nozzle 5-2	16:19:50	38.65	70.37	127.93	76.87	47.739	1.27
Spray Sys TX 4B 5 bar	21-Dec						
nozzle 1-1	14:46:00	39.57	75.33	147.33	84.86	51.484	1.43
nozzle 1-2	14:46:46	39.54	75.12	146.24	84.90	53.61	1.42
nozzle 2-1	14:47:28	40.20	72.46	143.74	83.82	56.567	1.43
nozzle 2-2	14:48:07	40.53	76.09	150.53	87.30	55.475	1.45
nozzle 3-1	14:48:45	39.40	77.10	153.11	87.93	53.873	1.47
nozzle 3-2	14:49:24	39.57	75.63	151.32	86.83	53.335	1.48
nozzle 4-1	14:50:10	39.95	74.79	157.88	87.81	53.584	1.58
nozzle 4-2	14:50:49	39.58	72.24	154.66	86.58	54.506	1.59
nozzle 5-1	14:51:37	38.32	72.14	140.31	81.16	50.839	1.41
nozzle 5-2	14:52:21	39.90	75.87	141.85	84.14	54	1.34
Spray Sys TX 6B 5 bar	21-Dec						
nozzle 1-1	15:51:18	40.81	90.10	167.09	98.44	58.853	1.40
nozzle 1-2	15:52:30	40.56	89.14	170.52	98.68	58.816	1.46
nozzle 2-1	15:53:09	40.86	88.75	172.96	99.92	60.617	1.49
nozzle 2-2	15:53:45	41.83	84.76	166.05	96.57	62.228	1.47
nozzle 3-1	15:54:24	40.68	83.54	165.53	95.33	58.523	1.49
nozzle 3-2	15:55:06	40.09	85.11	169.28	96.69	57.273	1.52
nozzle 4-1	15:55:44	40.33	87.27	166.79	96.08	57.253	1.45
nozzle 4-2	15:56:21	40.36	84.82	163.13	94.89	57.882	1.45
nozzle 5-1	15:57:00	40.69	82.77	169.81	96.52	59.207	1.56
nozzle 5-2	15:57:40	39.77	84.91	171.88	97.08	57.292	1.56
Spray Sys TX 10B 5 bar							
nozzle 1-1	16:43:00	44.92	103.40	205.15	117.26	72.778	1.55
nozzle 1-2	16:43:37	45.02	109.66	211.38	121.12	73.663	1.52

nozzle 2-1	16:44:15	43.44	99.06	198.45	112.51	68.862	1.56
nozzle 2-2	16:44:54	42.87	97.56	194.09	110.81	67.293	1.55
nozzle 3-1	16:45:37	44.03	98.85	201.56	114.19	70.869	1.59
nozzle 3-2	16:46:13	43.93	101.10	204.32	115.25	70.685	1.59
nozzle 4-1	16:46:51	44.17	102.59	205.93	116.91	70.698	1.58
nozzle 4-2	16:47:29	43.15	103.69	207.70	117.29	70.141	1.59
nozzle 5-1	16:48:09	44.07	107.16	212.43	119.93	71.546	1.57
nozzle 5-2	16:48:47	44.68	106.41	214.20	120.87	73.11	1.59
Spray Sys TX 12B 5 bar	21-Dec						
nozzle 1-1	16:19:50	46.74	115.75	232.99	129.66	78.57	1.61
nozzle 1-2	16:26:28	46.43	121.33	234.49	132.60	79.498	1.61
nozzle 2-1	16:27:08	47.77	124.17	246.37	137.84	82.58	1.55
nozzle 2-2	16:28:09	45.81	120.01	241.23	133.64	77.791	1.63
nozzle 3-1	16:28:50	45.21	110.12	228.51	125.69	75.841	1.66
nozzle 3-2	16:29:39	44.83	113.22	229.16	126.92	74.931	1.63
nozzle 4-1	16:30:34	45.20	114.71	238.45	131.14	75.024	1.68
nozzle 4-2	16:31:11	46.12	118.41	243.27	133.80	78.068	1.66
nozzle 5-1	16:31:49	46.76	115.81	229.62	128.68	78.624	1.58
nozzle 5-2	16:32:30	46.47	117.86	233.61	130.43	77.891	1.59

Spray Sys TX2B 7 bar	22-Dec						
nozzle 1-1	8:47:08	33.58	65.98	108.83	69.18	55.67	1.14
nozzle 1-2	8:48:13	33.06	66.43	108.97	69.31	54.986	1.14
nozzle 2-1	8:48:53	33.93	65.46	107.56	68.99	55.916	1.12
nozzle 2-2	8:49:32	33.27	65.62	108.12	68.77	55.995	1.14
nozzle 3-1	8:50:12	33.99	66.34	110.40	70.14	56.366	1.15
nozzle 3-2	8:50:50	33.89	66.13	108.11	69.35	55.423	1.12
nozzle 4-1	8:51:43	32.33	66.44	110.98	69.91	55.151	1.18
nozzle 4-2	8:52:22	33.60	66.51	110.57	70.23	55.329	1.16
nozzle 5-1	8:53:11	33.54	66.23	106.30	68.92	56.122	1.10
nozzle 5-2	8:53:50	33.28	66.87	107.37	69.31	56.414	1.11
Spray Sys TX 3B 7 bar	22-Dec						
nozzle 1-1	9:13:20	33.954	70.278	118.492	74.088	56.775	1.20
nozzle 1-2	9:14:21	34.065	69.869	114.169	73.18	58.638	1.15
nozzle 2-1	9:15:18	33.375	68.764	115.438	72.428	55.789	1.19
nozzle 2-2	9:16:09	33.897	69.414	116.019	72.97	55.736	1.18
nozzle 3-1	9:16:50	34.332	67.469	109.782	70.592	54.801	1.12
nozzle 3-2	9:17:31	34.078	69.914	114.316	72.682	55.542	1.15
nozzle 4-1	9:18:18	32.491	69.256	118.756	73.481	56.028	1.25
nozzle 4-2	9:23:41	33.058	69.535	118.043	73.926	57.489	1.22
nozzle 5-1	9:24:57	34.081	69.053	112.109	72.025	56.107	1.13
nozzle 5-2	9:25:58	34.95	69.21	114.005	72.619	55.945	1.14
Spray Sys TX 4B 7 bar	22-Dec						
nozzle 1-1	9:00:20	36.43	75.50	134.55	82.63	62.21	1.30
nozzle 1-2	9:00:58	36.42	76.71	134.26	82.99	62.856	1.28
nozzle 2-1	9:01:38	34.47	76.72	138.85	84.10	62.544	1.36
nozzle 2-2	9:02:36	35.39	75.42	137.83	83.05	62.648	1.36
nozzle 3-1	9:03:15	35.72	76.43	139.24	84.17	62.702	1.35
nozzle 3-2	9:03:57	35.89	77.25	139.33	84.75	63.818	1.34
nozzle 4-1	9:04:47	34.57	77.39	146.30	86.20	62.691	1.44
nozzle 4-2	9:05:26	34.93	77.38	145.45	86.24	63.642	1.43
nozzle 5-1	9:06:35	34.87	74.56	128.99	79.82	61.369	1.26
nozzle 5-2	9:07:13	33.77	73.07	126.61	78.47	59.623	1.27
Spray Sys TX 6B 7 bar	22-Dec						
nozzle 1-1	9:32:29	38.81	81.75	148.92	89.57	65.657	1.35
nozzle 1-2	9:33:25	37.09	80.02	143.75	87.18	64.986	1.33
nozzle 2-1	9:34:08	36.45	79.15	146.94	87.35	64.167	1.40
nozzle 2-2	9:34:45	36.65	80.96	150.49	89.54	65.451	1.41
nozzle 3-1	9:35:22	36.71	82.32	152.63	90.86	66.004	1.41
nozzle 3-2	9:36:03	35.23	81.32	151.42	89.70	67.097	1.43
nozzle 4-1	9:36:42	35.49	79.87	147.53	87.82	63.495	1.40
nozzle 4-2	9:37:20	37.38	81.87	150.16	89.96	65.792	1.38
nozzle 5-1	9:38:02	37.27	82.45	159.00	92.72	68.867	1.48
nozzle 5-2	9:38:42	38.87	85.13	162.41	94.43	69.389	1.45
Spray Sys TX 10B 7 bar							
nozzle 1-1	9:43:23	43.54	101.92	196.46	114.34	81.214	1.50
nozzle 1-2	9:44:03	46.54	104.30	200.74	115.47	82.182	1.48
nozzle 2-1	9:44:48	42.83	97.04	190.12	109.54	77.957	1:52
nozzle 2-2	9:45:28	42.19	97.86	189.92	109.91	78.502	1.51
nozzle 3-1	9:46:15	43.13	100.43	197.47	113.48	80.208	1.54

nozzle 3-2	9:46:54	44.35	101.18	197.85	113.92	80.77	1.52
nozzle 4-1	9:47:34	45.37	103.26	203.16	116.45	82.373	1.53
nozzle 4-2	9:48:19	44.80	99.14	198.87	113.78	80.545	1.55
nozzle 5-1	9:48:59	44.42	97.85	200.22	113.56	79.764	1.59
nozzle 5-2	9:49:40	44.16	103.64	202.59	117.02	82.774	1.53
Spray Sys TX 12B 7 bar	22-Dec						
nozzle 1-1	9:54:27	49.45	114.59	222.55	127.98	88.999	1.51
nozzle 1-2	9:55:07	48.03	115.00	223.84	126.82	87.909	1.53
nozzle 2-1	9:55:56	48.61	117.93	228.51	130.96	89.09	1.53
nozzle 2-2	9:56:35	48.29	118.38	229.81	130.77	89.288	1.53
nozzle 3-1	9:57:17	46.55	106.36	213.04	120.70	84.57	1.57
nozzle 3-2	9:57:57	46.48	108.64	213.79	123.01	85.476	1.54
nozzle 4-1	9:59:19	46.91	111.04	224.16	126.69	85.34	1.60
nozzle 4-2	9:59:59	47.02	110.30	228.71	127.09	86.485	1.65
nozzle 5-1	10:00:38	47.33	109.84	218.86	124.36	85.654	1.56
nozzle 5-2	10:01:17	47.16	109.74	218.75	124.37	86.544	1.56

Spray Sys TX 2B 10 bar	22-Dec						
nozzle 1-1	10:47:14	31.92	57.49	90.12	60.31	49.174	1.01
nozzle 1-2	10:47:53	31.60	57.67	90.11	60.40	49.775	1.01
nozzle 2-1	10:48:50	30.20	58.19	87.16	59.65	49.036	0.98
nozzle 2-2	10:49:41	31.12	59.08	88.60	60.60	50.171	0.97
nozzle 3-1	10:53:21	30.79	57.77	86.08	59.57	49.458	0.96
nozzle 3-2	10:54:01	30.00	57.35	86.67	59.29	48.795	0.99
nozzle 4-1	10:54:54	28.38	57.01	86.83	58.83	47.552	1.03
nozzle 4-2	10:55:32	29.38	56.94	85.75	58.68	48.318	0.99
nozzle 5-1	10:56:10	29.70	57.90	83.91	58.86	50.049	0.94
nozzle 5-2	10:56:59	29.06	57.75	83.01	58.36	49.763	0.93
Spray Sys TX 3B 10 bar							
nozzle 1-1	11:33:16	33.22	57.92	102.82	63.31	42.367	1.20
nozzle 1-2	11:33:56	33.83	57.37	100.38	62.49	41.519	1.16
nozzle 2-1	11:34:37	29.22	56.44	102.10	61.88	40.233	1.29
nozzle 2-2	11:35:16	28.57	55.02	98.53	60.21	39.776	1.27
nozzle 3-1	11:35:59	29.43	56.10	100.39	61.29	39.832	1.26
nozzle 3-2	11:36:37	28.47	56.96	103.27	62.51	40.282	1.31
nozzle 4-1	11:37:17	28.87	56.86	103.61	62.72	41.019	1.31
nozzle 4-2	11:38:40	29.64	56.52	104.47	62.41	39.573	1.32
nozzle 5-1	11:39:18	29.75	56.98	101.68	61.87	38.608	1.26
nozzle 5-2	11:39:57	30.17	57.54	100.05	61.97	41.76	1.21
Spray Sys TX 4B 10 bar	22-Dec						
nozzle 1-1	13:51:59	31.10	61.75	122.97	68.98	40.009	1.49
nozzle 1-2	13:54:03	31.17	62.17	123.27	69.43	38.456	1.48
nozzle 2-1	13:55:07	31.87	62.71	126.98	72.14	45.614	1.52
nozzle 2-2	13:55:51	30.32	60.52	125.91	69.09	38.596	1.58
nozzle 3-1	13:56:31	37.85	59.47	122.69	67.75	37.814	1.43
nozzle 3-2	13:57:36	30.81	60.82	124.96	69.09	39.08	1.55
nozzle 4-1	13:58:23	29.31	59.73	128.45	69.48	37.794	1.66
nozzle 4-2	13:59:06	29.50	59.70	129.51	69.58	38.505	1.68
nozzle 5-1	13:59:43	29.92	59.91	116.08	67.64	43.269	1.44
nozzle 5-2	14:00:19	29.90	59.90	114.31	67.22	42.977	1.41
Spray Sys TX 6BC 10 ba	22-Dec						
nozzle 1-1	13:39:14	34.06	74.24	147.31	88.55	50.163	1.53
nozzle 1-2	13:40:26	33.53	75.64	148.47	84.38	50.771	1.52
nozzle 2-1	13:41:28	32.27	74.97	152.68	85.08	49.629	1.61
nozzle 2-2	13:42:06	32.82	73.82	150.85	84.38	48.534	1.60
nozzle 3-1	13:43:08	33.82	79.17	164.42	91.55	52.276	1.65
nozzle 3-2	13:43:56	32.75	74.82	155.51	85.65	47.275	1.64
nozzle 4-1	13:44:40	32.11	74.90	153.20	86.36	55.213	1.62
nozzle 4-2	13:45:22	32.25	71.70	142.74	79.79	44.73	1.54
nozzle 5-1	13:46:04	32.77	71.89	150.19	82.77	43.637	1.63
nozzle 5-2	13:46:43	32.27	70.73	149.80	82.24	44.923	1.66
Spray Sys TX 10B 10 bar	22-Dec						
nozzle 1-1	14:07:14	37.13	92.65	192.64	106.32	56.063	1.68
nozzle 1-2	14:07:54	36.24	91.41	193.49	105.66	54.788	1.72
nozzle 2-1	14:09:21	35.99	88.53	185.77	101.99	53.629	1.69
nozzle 2-2	14:10:00	35.77	87.94	185.92	101.56	53.348	1.71
nozzle 3-1	14:10:42	35.87	88.83	190.63	104.34	53.773	1.74

nozzle 3-2	14:11:24	36.93	90.92	193.35	105.55	54.914	1.72
nozzle 4-1	14:12:07	37.18	92.14	198.25	107.79	57.093	1.75
nozzle 4-2	14:12:44	37.40	94.20	201.48	111.91	58.568	1.74
nozzle 5-1	14:13:35	36.88	92.38	199.12	107.61	55.884	1.76
nozzle 5-2	14:14:27	37.02	94.64	198.86	109.07	57.839	1.71
Spray Sys TX 12B 10 bar							
nozzle 1-1	14:19:57	39.03	104.131	216.359	118.3	62.695	1.70
nozzle 1-2	14:21:12	38.67	106.594	218.221	119.237	63.672	1.68
nozzle 2-1	14:21:50	39.067	110.254	227.352	123.316	64.942	1.71
nozzle 2-2	14:22:31	39.633	108.725	224.482	122.395	65.104	1.70
nozzle 3-1	14:23:12	38.946	100.879	211.846	115.716	62.424	1.71
nozzle 3-2	14:23:50	38.989	101.507	212.378	115.99	62.223	1.71
nozzle 4-1	14:24:34	38.909	103.251	225.086	120.122	62.978	1.80
nozzle 4-2	14:25:13	37.894	99.02	222.166	116.521	60.108	1.86
nozzle 5-1	14:25:51	39.429	105.9	217.813	119.316	64.469	1.68
nozzle 5-2	14:26:35	39.437	105.47	218.359	118.642	63.467	1.70