

## AGRICULTURAL PESTICIDE APPLICATION

### Concepts for Improvements\*

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#### Summary

The use of synthetic pesticides in agriculture is world-wide still the most widespread method for pest control. Environmental and human health problems related to the use of synthetic pesticides have created an increasing pressure against their use. Therefore non chemical alternatives for pest control have been developed and modern pesticides have become safer and more specific. Technical developments of the application equipment have kept pace to ensure an adequate application of these modern products. However, those technical developments regarding modern application equipment and it's professional use have not been transferred satisfactorily to field practice. In order to improve this situations the Agricultural Engineering Service of FAO has initiated a programme to create awareness for the issue on government level, introduce adequate practical training programmes for farmers and equipment operators and improve equipment quality through introduction of standards and regular tests.

**Keywords:** Pesticide Application, Equipment Standards, Training

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\* This paper reflects the personal views of the author and does not necessarily quote the official policy of FAO

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## **1. Use of Pesticides in Agriculture**

The use of pesticides in agriculture is world-wide the most common way of controlling pests. It is difficult to completely imagine the levels and security of today's yields without the use of synthetic pesticides. However, the irrational use of these products has led to serious problems and in some crops, like paddy rice in Asia, the costs of pesticide use are already higher than the benefits (Rola & Pingali, 1993). In crops like cotton, tomatoes or melons, difficulties in pest control using synthetic pesticides have forced farmers in some countries to abandon these crops completely.

There is a growing concern about the known and unknown consequences of pesticides on environment and human health, and in some countries there is already a strong public pressure to reduce their use.

Problems with the use of pesticides are usually worse in developing countries where many products of the WHO category I are still used. Those products being highly or even extremely toxic (WHO, 1992) lead to a considerable amount of poisoning. Some sources have reported up to 25,000,000 cases per year (Knirsch, 1994).

For these reasons, alternative approaches to pest control are used more and more and the concept of integrated pest management where synthetic pesticides are only applied as a last resort is now considered common practice in professional agriculture. The non-chemical alternatives include cultural practices, choice of resistant varieties, creation of an environment favourable for natural enemies of pests, and use of biological products and agents, including beneficial insects.

Under these conditions synthetic pesticides have undergone a development process to match with today's requirements. They have become less toxic for humans, though not necessarily for the environment, they have become more specific to act as a useful contribution within an IPM concept and they have become more powerful. While 40 years ago pesticides were applied in kilograms or litres of active ingredient per hectare, modern pesticides only require grams or millilitres to achieve the same or better result.

On the other hand, the new pesticides require a more sophisticated technology for an even and efficient application. Looking at biological agents for pest control their use can be increased by providing appropriate technology that allows for mechanized application on a large scale (Giles et al., 1995).

## **2. Development of the Application Technology**

Pesticide application technology has developed following the demand of the new approach to pest control and the pressure for the use of pesticides in a manner that is also safer for

environment and humans.

### ***2.1 Design Features***

The characteristics of modern application equipment allow a fairly safe and efficient application of pesticides of all kinds. This is valid for knapsack sprayers, tractor equipment and airplanes. The highest standards for application equipment are found in countries where legal requirements for human and environmental safety, as well as farmer's demands for efficient and exact application, have forced manufacturers to offer equipment that reflects the actual state of the art. This is the case in some European countries.

Some features of this category are, for example, filler openings, low level intake bowls, clean water tanks, the use of materials for tank and fittings chemical resistant and easy to clean, pressure control systems, boom suspensions, ergonomic features and others.

**The design of equipment has impact mostly on the operator and environmental safety preventing unnecessary contamination, accidents, losses and spills and allowing an even distribution of the product.**

### ***2.2 Monitoring and Controls***

The use of modern electronics has improved the accuracy of dosing and distribution. In general modern equipment uses electronic flow meters, pressure gauges, speed sensors and bord computers allowing the working parameters to remain within a pre-set value thus providing a much higher application accuracy than manual controls.

The use of global positioning systems (GPS) allows exact tracking of the swaths without use of landmarks or human flaggers; this represents an important safety improvement for aerial applications (Vetter, 1994).

Combining GPS technology with direct injection of pesticides into a water flow close to the nozzles allows patch spraying against certain weeds (Miller & Paice, 1995). Sensor controlled systems would only open the nozzle in case a target is appearing in front of it. These systems are used for weed control in dryland farming (Detectspray, 1993) as well as for modern tree crop sprayers where the potential for pesticide savings is 50 % (Perry, 1995).

**The use of electronics in modern application equipment allows exact dosing and can avoid off target spraying, thus contributing to product savings and therefore reducing environmental contamination.**

### ***2.3 Atomizer Technology***

Spray nozzles are one of the most important parts of a sprayer ensuring an environmentally safe and efficient application. Design features of hydraulic nozzles, still the most commonly used atomizers on pesticide application equipment, highly influence the output characteristics, spray pattern and droplet size distribution and thus the creation of the appropriate type of spray with a minimum of drift or off-target contamination. Among the latest developments are spray nozzles with variable orifice allowing a fairly constant droplet spectrum and spray angle over a range of pressure and flow rate (DLG, 1995).

Double flow nozzles improve the penetration of the spray into the crop and allow the adjustment of the droplet size without changing the flow rate (Thornhill & Matthews, 1995). Other nozzles draw the air into the nozzle body where it is mixed with the spray, creating air-bubbles inside the droplets (Göbel, 1995). Rotary nozzles allow the application of a very narrow droplet spectrum. The purpose of these developments is to

improve coverage and penetration with low volumes and reduced drift problems.

**The spray nozzle, although it would appear to be insignificant, is one of the most important parts of pesticide application equipment; modern spray nozzles represent a product of sophisticated engineering. The use of good quality nozzles has a very high potential for saving pesticides and reducing environmental pollution.**

#### ***2.4 Technology for Improved Penetration and Coverage***

Insecticides and fungicides acting by direct contact have to be applied with the best possible coverage. This is achieved with small droplets allowing at the same time cost savings by reducing the application volume (Pompe et al., 1992). However, under field conditions, the application of small droplets is prone to increase drift.

Air support systems, now available with boom sprayers, can reduce drift problems with small droplets increasing at the same time target coverage and penetration if set correctly (Jeffrey, 1994). Electrostatic charging of sprays to achieve the same effect is obviously also becoming popular again (McGill, 1995). Combining the air support systems with electrostatic charge of droplets could contribute to improving operator safety and reducing environmental pollution and application cost (Cooper, 1993).

**Application equipment that improves penetration and coverage with air-streams or electrostatic charges can contribute to a more efficient operation, thus reducing product losses. In addition, the use of lower application volumes which reduces the cost for the farmer is possible. In countries with a strong public and legal pressure on the use of pesticides and well trained farmers, the demand for those technologies is actually increasing.**

### **3. Field reality**

Unfortunately in many countries the pesticide application practised on field level is far from reflecting the actual state of the art. While modern pesticides have reached the most remote parts of the world, the technology used for their application often reflects technical standards of 40 years ago, resulting in a waste of pesticides and unnecessary environmental contamination. Cases have been reported where by only changing the nozzles of lever operated knapsack sprayers, 70% of pesticides could be saved compared to the farmer's previous practice (Stallen & Lumkes, 1990).

The Agricultural Engineering Branch of FAO has carried out studies in Central and Eastern Europe (Lavers, 1994) as well as in South America (Wiles, 1994) which showed various levels of deficiencies in the field of pesticide application technology.

#### ***3.1 Operator Knowledge***

Farmers' and application equipment operators' knowledge of the action principles of pesticides and the correct method of application is usually deficient or non existing. In many cases they do not receive any training on this issue (Heong et al., 1992). Already at University level the topic is often neglected. Therefore, extension services normally do not have technicians with a specialized knowledge of application technology. In many countries the only specialists offering practical advice to farmers on application technology, handling and calibration of their equipment are representatives of pesticide companies. However, they normally don't have a natural interest in showing the farmer how to save major quantities of the product.

There are several consequences of this lack of knowledge. Starting with the selection of equipment, a farmer without technical criteria will usually choose the cheapest equipment, possibly the most durable. Aspects of operator safety, comfort or efficiency

are of lesser importance, especially if the equipment is not operated by the farmer himself but by hired farm labour.

Another common problem is the use of excessive spray volumes and pressures. Application volumes of 6,000 l/ha in flowers and 10,000 l/ha in orchards have been reported (Wiles, 1994) causing run off of product and thus contaminating soil and probably groundwater resources.

**It is common that farmers and spray equipment operators still believe in high volumes, high pressure and high doses being perceived as the most appropriate ways for pesticide application.**

### ***3.2 Equipment Design***

In a free market situation and if the market does not demand quality, manufacturers are not encouraged to offer equipment with any extras to improve safety, comfort or efficiency, not considered essential for smooth functioning of the equipment. Some examples are:

- For knapsack sprayers:  
pressure regulators, wide straps and waist belts, long lances, quality nozzles
- For tractor equipment:  
boom suspension, anti-drip devices, easy draining tanks, appropriate controls

In addition, inferior materials often are used. Examples include tanks with rough surfaces, hoses or washers not being pesticide proof, and crimped hose clips. In some countries small workshops assemble spraying equipment from components without an idea of the basic principles of spraying. This sort of equipment competes on the market as it is sold at a very low price difficult to be matched by quality equipment.

In countries where the farmer as client does not have the technical knowledge to select good equipment and is mainly choosing by price, cheap equipment can force good equipment off the market.

**The lack of technical knowledge and awareness of farmers as clients as well as of manufacturers offering the equipment, are the main reasons for the low quality of equipment found in some countries.**

### ***3.3 Service Conditions of Equipment***

Usually the major part of the spraying equipment in use is in extremely poor condition, due to lack of maintenance. A report from the Philippines shows that a high percentage of farmers never change sealing washers in their equipment (Withaker, 1993). As a result, most spray equipment leaks. A study carried out in Indonesia reported that 58% of manual spray equipment leaked (Hirschhorn, 1993). Data from Nicaragua confirm this observation, mentioning pesticide spill over the operator's back from leaking knapsack sprayers, as being a common source of intoxications (Matus & Beck, 1991).

Nozzles are normally not replaced and are even enlarged on purpose to achieve higher flow rates. The distribution patterns under these conditions are uneven, leaving sections with no pesticide coverage and others receiving overdoses. At the beginning of a calibration programme for spray aeroplanes in Nicaragua, the majority of the equipment was found in bad condition as far as all components of the equipment were concerned (PAAT, 1992). Airplanes with defective anti drip devices releasing pesticides over populated areas were a common feature at that time.

**Again it is mainly the lack of technical knowledge and awareness of farmers and equipment operators that cause negligence regarding proper maintenance of the**

**equipment thus resulting in poor service conditions.**

#### **4. Concepts for Improvements**

##### ***4.1 Education and Training***

The lack of knowledge on all levels has been identified as the main reason for deficiencies in pesticide application practice. As a long term strategy this has to be addressed, beginning at the university level. The subject of pesticide application technology should be mandatory for agricultural engineers as well as for plant protection specialists.

On the other hand, practical training of farmers and equipment operators has to be introduced. The use of government extension services for this purpose has usually not proved to be efficient and sustainable. A better approach would be the creation of small groups of trainers dedicated specifically to this subject who are paid for their courses. Ideally these trainers should have a practical background, having operated spraying equipment themselves. They should be trained and kept up to date with refresher courses by master trainers. The established training capacity should cover the expected long-term needs. Training could begin strategically with contractors, offering service to other farmers and then be extended to private farmers and operators. The cost of the training could be paid by trainees, agro-chemical companies (preferable indirectly through taxes), by equipment manufacturers and, of course, by the government as a representative of the public interest in a safe environment.

The introduction of a mandatory license for pesticide equipment operators can help to increase farmers' interest in this training. Although it is always better to count on the awareness and voluntary participation, examples from Europe have shown that at a certain stage it is necessary to introduce legal pressure in order to assure interest in the training (Devereux-Cooke, 1995).

**The objective of the training programme should be to provide, in a sustainable manner, farmers and application equipment operators with the technical knowledge necessary for a safe and efficient application. The introduction of a mandatory license should never be an end in itself and only be considered if it contributes to more efficient training.**

##### ***4.2 Equipment Quality***

While in some countries there might be a need for training of equipment manufacturers, in the majority of the cases, the manufacturers are able to offer good quality equipment if the market demands it. In these cases, incentives for improved quality have to be introduced. In many developing countries the demand is due to lack of knowledge not leading in that direction. There the only solution is to limit the market access to quality equipment only, introducing a certification system based on technical standards for application equipment.

For a government to introduce such a certification system, it is not necessary to have its own test centres or to test each piece of equipment themselves. On the other hand, a certification system can also be introduced on a voluntary basis by manufacturers and their organizations using the certificate as a quality trade mark and for sales promotion.

A certification system can only be implemented if there are approved national standards for that kind of equipment.

Technical standards have two aspects. One is to describe minimum requirements of the equipment in order for it to be approved or certified. This type of standards will usually be used for an official certification system. Standards could also describe the desired level of technology in order to induce improvements in equipment quality. These standards can be

introduced by manufacturers' or users' organizations who provide a quality seal for equipment fulfilling the requirements.

Standards will have to be dynamic and reflect the actual technological development and scientific knowledge.

**The introduction of standards or a certification system is no end in itself. They should be used to guarantee a minimum quality of equipment available on the market and induce technological progress.**

#### ***4.3 Equipment Testing***

Apart from the standards of new equipment, the working conditions of application equipment in actual use give reason for concern. Therefore, structures have to be implemented to ensure the proper operation of application equipment. The necessary checks and repairs can be carried out by the commercial sector. Especially in an introductory phase this approach should be the first choice to convince the involved parties of the benefits this activity provides for each of them. The farmer saves money through reduced pest control costs by using a properly adjusted and calibrated equipment and the commercial sector earns by providing the service or even selling the required wear parts.

The test service can therefore be provided through agricultural equipment dealers and workshops, extension services, or government entities. In any case, it should pay for itself through fees.

Eventually it might become necessary to introduce mandatory check systems. In Germany, this system was introduced in 1993 after past experience with voluntary checks which had only been used by 20% of the farmers. As in these checks only 50% of the equipment was found in perfect condition, the government decided to introduce mandatory checks (Wehmann, 1993). In Nicaragua mandatory checks on spray aeroplanes were introduced in 1991, following a one-year voluntary check with a heavy publicity campaign. By that time the checks were widely accepted and the introduction of mandatory checks did not cause any problem (Friedrich, 1995). However, mandatory checks can only be introduced after the infrastructure to carry out the checks is installed.

**Regular checks of pesticide application equipment should be promoted in a way that all participants see a clear advantage for themselves.**

#### ***4.4 Infrastructure Aspects***

Pesticide application is becoming more and more complicated. As a result in some countries this work is increasingly being taken over by contractors who specialize in the subject and make use of the latest developments in application equipment.

On the other hand equipment dealers and sales outlets are an important issue. In many countries, the salesperson is the only contact the farmer has for technical advice. Therefore, dealers selling pesticide application equipment should in the same way as pesticide dealers receive special training and probably require a license to sell those products. Situations should be eliminated where spraying equipment is sold in general country stores without any technical advice, spare part supply or repair service. Application equipment should be sold through specially qualified sales outlets. These can be either pesticide dealers or agricultural equipment dealers (Dandy, 1994).

**The training of those distributors together with their mechanical repair workshop operators could be financed by equipment manufacturers or other private enterprises. The government's role would be to monitor the sector and, if necessary, introduce a licensing system.**

## 5. FAO Activities in Pesticide Application

For many years now FAO has been dedicated to promoting a rational use of pesticides. The most visible work in this respect was probably the introduction of the [International Code of Conduct on the Distribution and Use of Pesticides in 1985 with the Prior Informed Consent in 1989 \(FAO, 1990\)](#).

Already in 1985, a FAO Panel of Experts Working Group on Pesticide Application Standards highlighted the importance of equipment standards and appropriate training programmes (FAO, 1986).

The issue was taken up again by FAO in 1994 with the introduction of a Programme for Safe and Efficient Application of Agro-chemicals and Bio-products. The objective of the programme is to create awareness and establish the basic structures in FAO member countries for the introduction of sustainable long-term improvements in pesticide application practice at the field level.

The programme is oriented toward experiences of countries advanced in pesticide application technology. These experiences show that, in general, apart from awareness and knowledge, legal pressure is required to introduce good practice. The relation between awareness and pressure, however, depends on the current condition of each country and therefore has to be decided individually. The programme consists of a series of alternatives which can be selected and adapted according to the need of a specific country.

The programme was first started with two workshops in 1995, one for Central and Eastern Europe and one for the South Cone of Latin America.

An important activity within the programme is the formulation of FAO standards for the most common types of agricultural application equipment. These standards are limited to aspects of safety and efficiency and should be applicable world-wide.

The set of standards consist of two groups:

1. Guidelines for the Basic Requirements for Pesticide Application Equipment: These guidelines reflect the absolute minimum requirements for application equipment actually met by the majority of equipment commercially available world-wide. Their immediate use is standard for FAO's purchase of equipment. However, they will be sent to other donor agencies and FAO member countries for their adoption.
2. FAO Standards for Pesticide Application Equipment: These are more comprehensive standards, including test procedures that would lead to the status of "FAO-Approved equipment". After official adoption by FAO, these standards will be forwarded to FAO member countries as guidelines for the code of conduct and proposals for the introduction of harmonized national standards.

**The programme starts usually with a regional workshop to create awareness among government representatives, farmers and the commercial sector. The situation is presented, problems and possible solutions discussed. Implementation remains the responsibility of each country. FAO offers technical assistance if needed and provides a follow-up of the implementation.**

## 6. Conclusion

To effectively improve pesticide application practices, the introduction of standardized good quality equipment and operator training seems to be necessary (Pingaly, 1994).

Technology allowing a reasonably safe and efficient application of pesticides exists as well as concepts to introduce its use in practice. However, those concepts have to be adapted

to the specific situation in each country. Their introduction depends very much on the technical capacity, organization, cultural background and good will of the people involved.

**The role governments have to take is comparable to the one of an orchestra conductor, the orchestra being the private sector. The challenge is not so much in technical details but in co-ordination of the activities to guarantee that everyone is contributing his best. As in a concert, the programme will only be successful if every player performs responsibly and in harmony with the others.**

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