Application Technology: Problems and Opportunities with Knapsack Sprayers, Including the CFValve™ or Constant Flow Valve

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Abstract

Small-scale farmers and other applicators maintain a high level of interest in the lever-operated knapsack because of its versatility, cost and design. However, this equipment can lead to misapplication of chemicals and ineffective control of the target pest. The design, construction and limitations of the lever-operated knapsack sprayer are discussed. Lack of pressure control is the single biggest limitation in the use of these sprayers. Lack of pressure control can lead to variable flow rates (dosages) of chemical preparations, inconsistent spray pattern and spray droplet size, all of which affects spray coverage and chemical performance. Variable pressure can also influence the drift of spray particles reducing crop coverage and exacerbating worker exposure to the chemicals. The CFValve™ is a product designed to maintain constant pressure at the nozzle for manual spray equipment. This valve allows an applicator to apply a careful, directed spray at a consistent rate. When used in combination with appropriate nozzles, the valve allows consistent spray characteristics throughout the entire application optimally suited for chemical control of the pest. The paper discusses the function of the CFValve™ and the benefits of using the device. Recommendations for using the valve with fungicide applications are provided.

Resumen

McAuliffe, D and Gray V. P. 2002. Tecnología de aplicación. Problemas y oportunidades con bombas de mochila incluyendo la Válvula CFV™ o la válvula de flujo constante. pp. 81–91 en: Fernández-Northcote E. N. (ed), Memorias del taller internacional Complementando la resistencia al tizón (*Phytophthora infestans*) en los Andes, Febrero 13–16, 2001, Cochabamba, Bolivia, GILB, Taller Latinoamérica 1. Centro Internacional de la Papa, Lima, Perú.

Los pequeños agricultores y otros aplicadores mantienen un alto nivel de interés en los pulverizadores de palanca o bombas de mochila debido a su versatilidad, costo y diseño. Sin embargo, este equipo puede llevar a una mala aplicación de productos químicos y a un control inefectivo de la peste problema. En el presente trabajo se discute el diseño, construcción y limitaciones de las bombas de mochila. La falta de control en la presión de operación es el mayor limitante en el uso de estos pulverizadores de palanca. Esta falta de control puede llevar a tasas de flujo (dosis) variables del líquido asperjado, patrones de aspersión y tamaño de gota asperjada inconsistentes, todo lo cual afecta la cobertura de la aspersión y la perfomance del producto químico. La presión de operación variable también puede afectar la deriva de las partículas asperjadas, reduciendo la cobertura del cultivo e intensificando la exposición del aplicador a los químicos. La válvula CFValve™ es un producto diseñado para mantener una presión de aplicación constante en la boquilla de los equipos manuales de fumigación. Esta válvula permite al operador realizar una aspersión cuidadosa y precisa a una tasa de flujo constante. Cuando se usa en combinación con boquillas apropiadas, la válvula permite realizar aspersiones de una característica consistente a través de toda la aplicación y en condiciones óptimas para el control químico de la peste. Se discute la función de la válvula CFValve™ y los beneficios de su uso. Se indican recomendaciones para el uso de la válvula en las aplicaciones de fungicidas.

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Introduction

The lever-operated knapsack is the most common type of spray equipment used for crop protection in countries of the developing world. However, accurate and consistent pesticide applications are difficult to manage because this type of spray equipment has little or no pressure regulation. As a result, crop protection chemicals are often misapplied, leading to poor biological results, unnecessary chemical exposure to the applicator and the environment, the exacerbation of resistance to pesticides, and added expense of already cash limited farmers.

The knapsack sprayer offers many advantages to the small farmer and it will continue to be the single most important method of chemical application with these farmers. Overcoming the problem of pressure and flow control for the knapsack sprayer would substantially further the benefits of this equipment. This paper discusses the function, advantages, and limitations of the knapsack sprayer. It also discusses the development and utility of a constant flow valve that adds the pressure and flow control desperately needed for knapsack sprayers.

Lever operated knapsack sprayers

The conventional knapsack sprayer design has changed little since it was first developed in the late 1800's (Matthews 1969). However, interest has remained high with this type of equipment as its versatility in use with different types of pesticides suits the requirements and resources of small-scale farmers aiming to increase agricultural productivity under harsh conditions in developing nations. New innovations in plastics and metals, making sprayers lighter in weight and more efficient in pumping, have made knapsack sprayers easier to use, particularly in areas with excessive heat and difficult terrain. Because a wide range of brands and ergonomic designs of knapsack sprayers are currently available on the market, the farmer or pesticide applicator can select one based on his or her physical stature and capability (strength).

Description:

A manually operated knapsack sprayer (Figure 1) consists of a tank, 10 to 20 liter capacity, which is carried on the back by two adjustable shoulder straps. An operating lever, positioned either over the shoulder or under the arm, drives a piston or diaphragm pump. The under arm lever can often be adjusted for use with the right or left arm, and the over the shoulder lever can be operated with either arm. A waist strap is sometimes used to provide support, hold the tank firmly in place, and ensure that the operator's pumping energy is more efficiently transferred from the lever to the pump. The pump is most commonly fitted on the inside of the tank to prevent damage, but is also found fitted on the outside of the tank, which allows for easy maintenance.

Constant pumping is required to operate a knapsack sprayer, and the decision to use a piston or diaphragm pump should be based on the type of application to be made. Piston pumps are preferred for applying insecticides and fungicides because they are able to achieve pressures of 2.0 bar or greater (FAO, 1994), with relative ease. In this system, liquid is drawn from the tank through a valve into the pump chamber by the upward movement of the piston. On the reverse stroke of the lever, the spray solution passes through a second valve into an air or pressure chamber. This air chamber forms part of the piston on many sprayers.

Structurally, the air chamber is an important component of a knapsack sprayer. Air is trapped in part of the pressure chamber and compressed as liquid is forced into it. Subsequently, as pressure in the air chamber increases, liquid is directed through a dip tube and hose, past a trigger valve, and through a lance to the nozzle (FAO, 1994, Matthews, 2000). While the size of the pressure chamber varies on different types of knapsack sprayers (160 to 1300 ml) (Matthews, 2000), the air chamber should be as large as possible, and at least ten times the pump capacity (FAO, 1994, Matthews, 2000). Regardless of pressure chamber size, fluctuations in pressure will result from the pumping action of the applicator, however, these variations in pressure are considerably worsened if pressure chamber capacity is inadequate (Matthews, 2000).

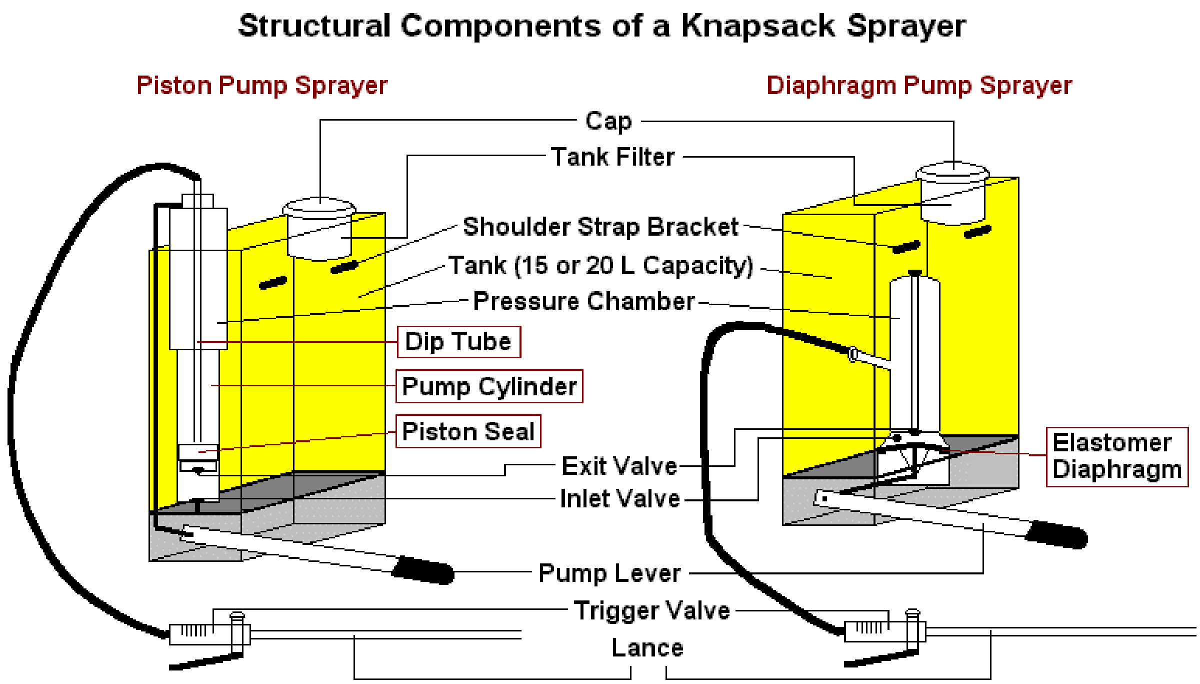

Figure 1. Structural components of a knapsack sprayer.

When pump displacement and pressure cylinder capacity is small, more effort is required to operate the sprayer, especially at higher pressures (Matthews, 1969). Diaphragm pumps have a flexible elastomer diaphragm, usually located at the base of the tank, in place of a sealed piston. Due to the limited up and down movement of the diaphragm, these types of sprayers are generally less efficient. They require a stronger force on the lever than do piston pumps and a higher mean number of strokes per minute to achieve volume per hour output at various pressures with various nozzles (Matthews, 1969). Therefore, diaphragm pump knapsack sprayers are more suited to low pressure applications.

Opportunities:

As opposed to tractor pulled or larger mechanical equipment, manually carried equipment allows for greater maneuverability throughout crop fields, which are often located on variable terrain. While mechanical equipment requires treatment of whole areas during application, the knapsack sprayer allows spray solution to be directed to the biological target, thereby allowing the operator to reduce as much as possible the total amount of pesticide applied (FAO, 1994). Therefore, the knapsack sprayer allows the small farmer to be more efficient and selective in chemical use than he would be with mechanized equipment.

The relatively low cost of knapsack sprayers requires a minimal initial investment when compared to other options for application equipment. However, maintenance and durability play a crucial role in the function and useful life of a knapsack sprayer. Most growers select a knapsack sprayer based on price and availability. When sprayers are used under field conditions several hours a day for several days a week, significant stress on internal components drastically reduces the efficiency and service life of the knapsack sprayer (Matthews, 1969). Difficulties with maintenance, such as time constraints, inadequate tools, lack of technical training, and insufficient supply of spare parts, reduce the importance of the initial cost. Criteria for selecting knapsack sprayers should therefore be based on ease of operation, reliability, durability, and simple maintenance requirements (Matthews 1969).

Problems:

The single biggest limitation to the operation of a knapsack sprayer is the lack of pressure control. Knapsack sprayers vary widely with respect to pressurization capacity among different brands of sprayers, and even among different models of the same brand (Matthews 1969). Variations in pressure are a result of any number of factors and have a detrimental effect on the consistency of spray pattern from the nozzle, and subsequently, on the overall quality of the pesticide application.

Pressure Fluctuations:

Along with the particular construction of the sprayer, the force exerted on the lever by the applicator and the frequency of the pumping action (length and speed of the stroke) are perhaps the most significant factors affecting pressure fluctuations with knapsack sprayers. As pressure varies at the nozzle, flow of the spray solution fluctuates significantly, resulting in an inconsistent dosage of the chemical applied. Inconsistent dosage and spray volumes reduce the biological and cost effectiveness of pesticide applications with knapsack sprayers.

Depending on the nozzle type and size, the operating pressure of a sprayer can have a significant effect on spray angle. In addition to inconsistencies in flow rate, fluctuations in pressure at the nozzle contribute to inconsistencies in spray pattern and coverage of the target pest, crop, or soil. When pressure increases with the downward stoke of the lever, the angle of the spray from the nozzle increases to cover a wider area. This is the spray swath width. Swath width declines as pressure at the nozzle decreases, such as when the operator "relaxes" his or her pumping rate. The variable patterns created by these pressure fluctuations are especially notable with flat fan type nozzles, which are labeled according to spray angle and flow rate. For example, a standard "8002" flat fan nozzle is designed to create an 80° angle and have a flow rate of 0.20 gallons per minute at a pressure of approximately 3 bar (44 psi). If an 8002 nozzle is operated at approximately 1 bar (15 psi), the spray angle changes to 65° and the flow rate declines to 0.12 gallons per minute (Figures 2A, 2B). When these types of nozzles are used for broadcast applications, 30% overlap of spray pattern is recommended to achieve good coverage. This is extremely difficult to achieve when the swath width fluctuates.

Essential to accurate, quality chemical applications is the ability to calibrate the spray equipment. Calibration itself depends on a measured and consistent flow rate and spray swath from the nozzle. Sprayer calibration is based on the premise that flow rate and pressure should remain constant. Without a pressure-regulating device, flow rate may be averaged per minute, but change in flow rate throughout the application make consistent applications with even distribution of chemical impossible.

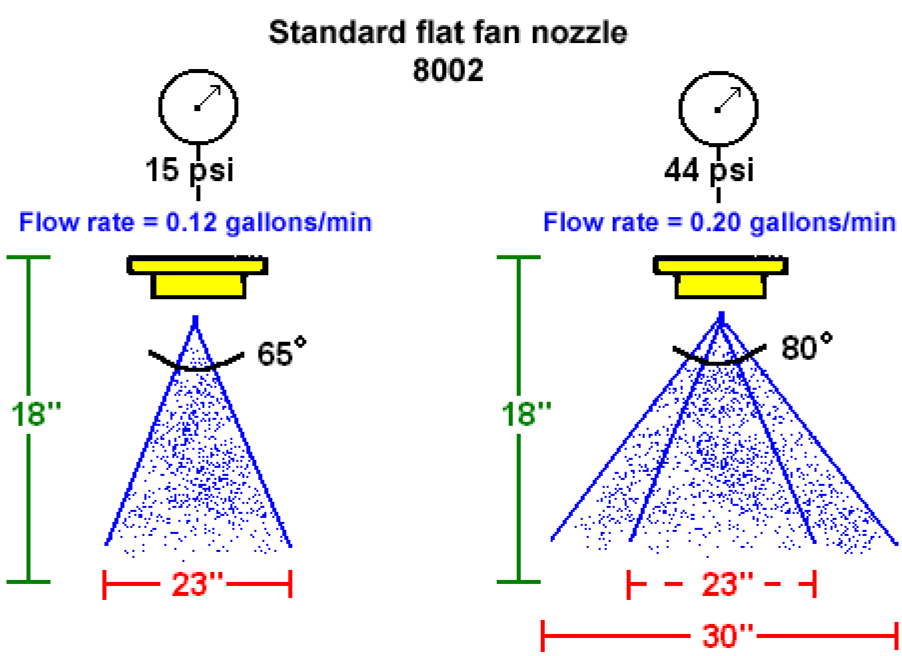

Figure 2A: Pressure fluctuations and its effect on spray angle.

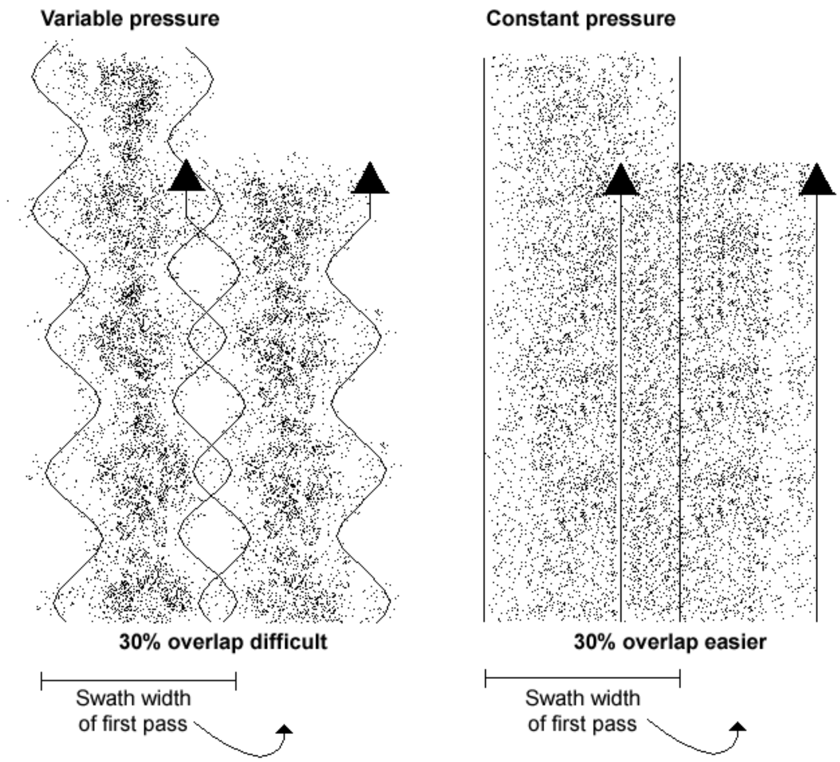

Figure 2B: Pressure fluctuations and its effect on swath width.

Pressure and Spray Drift:

Inconsistencies in spray pressure result in inconsistencies in droplet size and spectrum. On the downward stroke to the lever, pressure peaks can reach as high as 3 to 5 bar (Eng et al., 1999, McAuliffe, 1999). This level of pressure, in conjunction with the type of nozzle typically used with knapsack sprayers, can result in the formation of a high percentage of fine droplets prone to drift. In one study, a Jacto # 12 hollow cone nozzle (Flow rate = 250 ml/min at 1.4 bar (20psi)) was evaluated for droplet size spectrum at different pressures. As pressure was increased in increments of 0.70 bar (10 psi) between 1.40 to 5.50 bar (20 to 80 psi), the volume median diameter (VMD) for the Jacto nozzle steadily decreased from 166 to 116 microns. The increase in pressure also resulted in a significant increase in the percentage of droplets by volume under 150 microns (McAuliffe, 1999). Since droplets less than 100 to 150 microns are considered drift prone (Matthews, 1997), this variation substantially increased the potential for drift. With the increase in the potential for spray drift, the chance of off-target deposition of spray solution increases dramatically (McAuliffe, 1999). Furthermore, fine droplets of water have a very short lifetime due to evaporation, particularly in dry areas with excessive heat (Matthews, 2000), thereby reducing chemical efficacy.

Effects of Spray Drift:

In addition to being an important issue with regard to both coverage of the biological target and chemical deposition, spray drift has increased concerns worldwide about the presence of pesticides in the environment. If a pesticide looses part of its diluent due to evaporation, a small particle of concentrated chemical remains, which can be carried significant distances by airflows, sometimes several kilometers from the site of application (Matthews, 2000). Such concentrated droplets moving off-target can cause contamination of crops and the environment, particularly in sensitive areas located near water. Of particular concern with knapsack sprayers is the close proximity of the applicator to the chemical spray, relative to tractor-mounted or larger mechanical spray equipment, and the greater likelihood of contamination with the pesticide (Matthews, 1999).

Constant flow valve or CFValve™

The importance of pressure control to the quality of chemical applications has been largely underestimated and under-emphasized by Crop Protection Chemical Companies and knapsack sprayer manufacturers. Some knapsack sprayers come equipped with pressure gauges. However useful, gauges should not be considered a means of pressure control. Some knapsack sprayer brands have an adjustable pressure relief valve. Designed as a pressure limiter, they work by recycling liquid to the tank through a by-pass once the pressure in the pump exceeds a particular setting. Pressure relief valves provide limited pressure control, however pressure fluctuations at the nozzle still occur. Furthermore, pressure relief valves are located on the inside of the tank, exposing the applicator to contamination when attempting to adjust the setting. While the return flow can provide some agitation in the tank, once the input pressure exceeds the setting, operator energy expended for pumping the sprayer is wasted.

Recently there have been new devices produced to improve pressure and flow control with manual equipment. However, to be utilized for the majority of knapsack sprayers, such a device needs to be accurate, effective, durable, have little chance for operator error, and be affordable, especially for small-scale farmers with limited resources. The CFValve™ or Constant Flow Valve satisfies all the criteria required of a pressure control device. The CFValve™ was co-developed by Global Agricultural Technology & Engineering, LLC (G.A.T.E.) and E.I. DuPont de Nemours Co., Inc, with the intent of providing a solution to pressure variations specifically for knapsack sprayers.

Description:

The CFValve™ (Figure 3) is a pressure and flow control valve designed to allow the applicator to effectively manage the flow of spray solution from the nozzle by ensuring that the pressure at the nozzle is constant despite the variations in pressure caused by the pumping action of the applicator (McAuliffe, 1999). The main components of the CFValve™ are: 1) a stainless steel metering pin located on the inlet side, 2) an interior chamber containing a spring, 3) and a diaphragm made of elastomer, which seals the interior chamber (Figure 4). The CFValve™ works by detecting the input pressure from the pump and the back-pressure from the nozzle, and modulates the size of the inlet orifice accordingly to maintain a constant output pressure throughout the application.

The CFValve™ serves as a check valve as well. Once the input pressure reaches the opening pressure of the CFValve™ (a pressure slightly greater than the pre-set regulating pressure of the CFValve™), the CFValve™ opens and maintains output pressure constant at the pre-set regulating pressure. Input pressure can reach as high as 6 or 7 bar (Figure 5), however, the output pressure will remain at the regulating pressure with 1.5% variation in flow rate from the nozzle. As pressure declines just below the regulating pressure of the CFValve™, the valve shuts off and stops flow completely.

The commercial valves are made of a durable Delrin®[2] plastic and are available in 4 pre-set pressures (1.0 bar, 1.5 bar, 2.0 bar, and 3.0 bar), color-coded according to pressure (Yellow, Red, Blue, Green, respectively). The CFValve™ is simple to use because there are no adjustments. They are available in 5 different thread sizes to fit most brands of knapsack sprayers. Placed at the end of the lance before the nozzle, the CFValve™ is light in weight (19 grams), and does not put any undue stress on the wrist or hand of the applicator (McAuliffe, 1999). Because of the linear design of the valve, the lance can be handled as it would without the CFValve™.

Benefits:

The elimination of pressure fluctuations using the CFValve™ has been shown to substantially improve the quality of chemical applications using knapsack spray equipment. Inconsistencies in flow rate from the nozzle, spray pattern, and droplet size spectrum are eliminated, thereby allowing the user to apply the spray solution uniformly throughout the treated area (Eng et al., 1999; McAuliffe, 1999). The flow control achieved using the CFValve™ allows the grower to precisely calibrate his knapsack sprayer and apply chemicals as per the label rate specified by the manufacturer.

[2] Delrin ® is a registered trademark of E. I. DuPont Company.

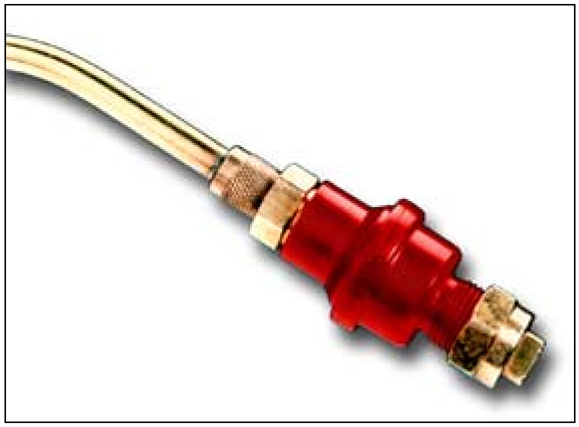

Figure 3. Metal lance, CFValveTM and nozzle.

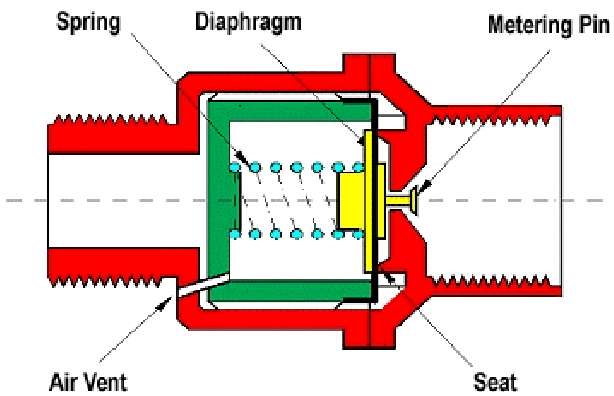

Figure 4. Cross-section of CFValveTM (with permission of Sprays International Ltd.)

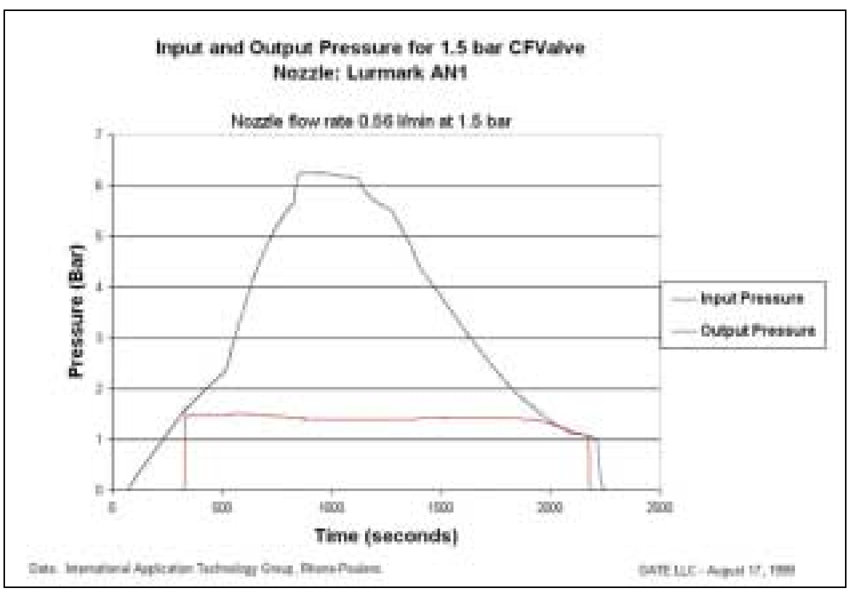

Figure 5. Input and output pressure for a 1.5 bar CFValveTM with a Lurmark AN1 nozzle.

Using the CFValve™ also allows the operator to select the most appropriate nozzle for a particular application. As swath width is maintained, the necessary overlap needed by standard flat fan nozzles, for example, can more easily be achieved and will improve coverage.

The CFValve™ has been shown to reduce the variability of droplet size and the number of fines produced by a given nozzle (McAuliffe, 1999). The elimination of the potential for spray drift is important to chemical deposition and coverage. With the applicator's downstroke to the lever, over-application of water and chemical usually occurs because of the high pressure generated. When chemicals are mixed on a concentration basis, the use of a CFValve™ can reduce water and chemical use from 28% for over-the-top treatments to 50% for up-and-down, vertical movements of the lance between individual mature plants. In various studies using the CFValve™, pest control levels improved (Eng et al., 1999) and/or remained the same (McAuliffe, 1999). These chemical savings indicate that the pesticide is over applied at times because of momentary high pressure and that the management of droplet size by the CFValve™ improved the efficiency with which chemicals penetrate the canopy, increased the chance for on-target deposition and minimized drift (McAuliffe, 1999).

The incorporation of the CFValve™ into standard knapsack spray equipment provides substantial benefits to the applicator. Reductions in spray drift potential using the CFValve™ have reduced the chances of worker exposure to harmful pesticides. In separate studies, significantly lower levels of contaminants were found on the front, sleeves, and thighs (Shaw, 1999; Eng et al, 1999) of applicators using the CFValve™ in controlled field experiments.

Regardless of the type of sprayer (piston or diaphragm), pump displacement, and air chamber or pump cylinder capacity, using a CFValve™ reduces the amount of work effort needed to operate a knapsack sprayer and achieve an adequate spray pattern from a given nozzle. At a given pressure, the number of pump strokes per minute to the lever is reduced because the operator's energy is stored in the spring of the CFValve™ and the pressure chamber of the sprayer. The CFValve™ theoretically extends the life of a knapsack sprayer due to the reduction of mechanical action and the wear on the pump, making knapsack sprayers more cost effective to the grower. Using a CFValve™ therefore improves the overall efficiency of the application, the applicator, and the equipment.

Considerations:

Maintenance plays an important role in the quality of a chemical application. Decreased efficiency of a knapsack sprayer also has an affect on the work effort needed to use a CFValve™ with a sprayer. For example, if a particular sprayer leaks or the seals are worn, it is more difficult to achieve a given pressure, with or without a CFValve™, than if the sprayer were new or in good working order. The sprayer needs to generate at least enough pressure to open the CFValve™ used. For high, pre-set CFValve™ pressures, the CFValve™ will be more difficult to use in conjunction with a diaphragm sprayer than with a piston sprayer because diaphragm pumps are less efficient.

Regardless of sprayer type, field experience has demonstrated the difficulty of knowing the working pressure during an application. On some occasions, applicators believe they have been spraying at 2.0 bar, and applying a specific volume of spray solution per area with a given nozzle. However, after fitting a Blue, 2.0 bar CFValve™ to the knapsack, the applicators had difficulty maintaining the CFValve™ function, and were exhausted after only a few minutes of constant spraying. This experience indicates that many applicators do not know the pressure at the nozzle, and work under incorrect assumption to determine the amount of chemical to apply. Also, while they may or may not have been spraying at 2.0 bar when the sprayer was new, extensive wear on various knapsack sprayer components made it too difficult for the applicators to achieve higher pressures. In the absence of a pressure gauge, a CFValve™ has the added benefit of being diagnostic for sprayer function. If a sprayer is unable to open and effectively use a CFValve™ to manage a given application, the applicator can either use a lower pressure valve and calibrate the application accordingly, or repair the sprayer to achieve the desired higher pressure.

The CFValve™ itself requires minimal maintenance. It is "self-cleaning" and does not clog because the inlet orifice is the smallest passage. Good spray practices recommend including the use of strainers or filters at multiple points in the sprayer such as the fill port to the tank, the handle, and at the nozzle prior to the CFValve™. Such filtering ensures a continuous spray pattern from the nozzle and minimizes nozzle clogging and wear. A 50-mesh filter is adequate, however with nozzles smaller than a 0.8 liters per minute (0.2 gallons per minute), a 100-mesh filter is recommended (Matthews, 2000).

Once the input pressure declines and the CFValve™ shuts-off, pressure is maintained in the lance between the trigger and the CFValve™ and nozzle. If the CFValve™ is removed immediately after application, the pressure in the lance will cause a few drops of spray solution to be released. It is recommended to flush the system with clean water before removing the CFValve™.

Fungicides and knapsack sprayer technology. CFValve™/Nozzle selection and recommendations

Emphasizing the importance of pressure and flow control to growers using manual equipment is challenging but necessary to effectively manage crop protection. This is especially true for fungicide sprays to potatoes since reducing the amount of fungicide applied and the frequency of applications is necessary in order to reduce the development of resistant strains of late blight (Matthews, 2000). As demonstrated previously, the lack of pressure control on standard knapsack sprayer equipment results in over application and inconsistencies in application, all of which can lead to poor control and a greater potential for resistance development. Application of contact fungicides such as copper sprays requires careful directed application to infected areas (FAO, 1994). Yet losses of spray solution due to evaporation and poor spray deposition as a result of drift and inconsistent flow of spray solution often means repeat applications are necessary at shortened intervals. The most important factor in applying fungicides is making sure the optimum dosage reaches the part of the plant canopy where the infection is located (Matthews, 2000). Incorporating the CFValve™ into existing equipment can significantly help to achieve this goal.

Typically, pesticide manufacturers recommend the optimum volume of spray to be applied with suggested nozzle sizes. However, droplet size, chemical distribution and coverage of the leaf area are extremely important, and can vary depending on the plant architecture, stage of plant growth, leaf area index, and plant density. Hollow cone nozzles are generally recommended for fungicide applications because the variable range of droplet sizes produced by a single nozzle approach the leaves from multiple directions (Matthews, 2000). Coverage of the underside of the leaf is essential for good control of late blight and any apparatus or technique that improves coverage on the bottom of the leaf would further improved control when using a knapsack sprayer. One such method of spraying is to attach a fitting that allows the direction of spray to be altered as needed. The lance end can be modified so that the cone nozzle is held in the inter-row below the leaf canopy and oriented so that the spray is directed upward at the bottom side of the leaves (Figure 6). This allows droplets to impact lower leaf surfaces and any excess spray solution would pass through the plant and fall back to the upper leaf surfaces of the potato plant. This technique has been recommended for cotton insecticide spraying by Graham A. Matthews and should be considered as an effective method for improving control of late blight in potatoes.

Increasing spray volume does not necessarily improve coverage (Matthews, 2000). With standard equipment, increasing the volume applied by increasing pressure will result in the creation of more fines and higher drift potential. It can also lead to significant run off from the leaf surface. Changing the flow rate by increasing nozzle size will result in a coarser spray, which is not necessarily optimal for fungicide applications. Increasing the flow rate through pressure or larger nozzles merely results in increased chemical deposition either off-target due to drift, or on exposed leaf areas only. Little or no improvement in pest control will be achieved where the inoculum is concentrated, often on the underside of leaves or within the crop canopy (Matthews, 2000).

It is also generally recommended that fungicides be sprayed at higher pressures (2.0 bar and greater) in order to achieve better coverage (Matthews, 2000). However, depending on the type of sprayer used (diaphragm or piston) and the condition of the sprayer, working consistently at 2.0 bar or greater is difficult. Applicators may begin working early in the morning at high pressure, but are tired at the end of the day. Therefore, the first hectare applied may have over-application of chemical, while the last hectare may be under-applied.

By choosing the adequate combination of pre-set CFValve™ pressure and hollow cone nozzle, a grower, researcher, or extension agent can achieve an optimum balance among droplet size (VMD) and spectrum, working pressure, consistent flow rate required for the specific application, and the effort required to spray the crop.

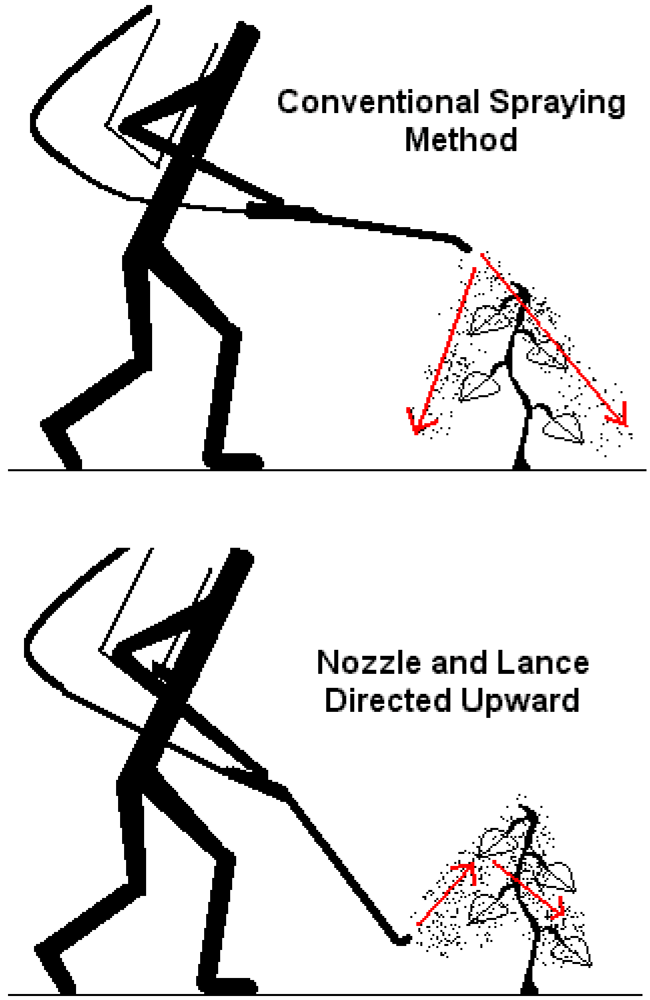

Figure 6. Conventional and upward pointed nozzle spraying methods.

Conclusion

The lever operated knapsack sprayers continues to be the most common piece of application equipment for crop protection in many countries. Its versatility in use with a variety of different chemical products and its relative ease of operation make it well suited for small-scale growers aiming to increase agricultural productivity. However, the problem of pressure variations caused by the pumping action of the applicator can have detrimental effects on flow rate, droplet size and spectrum, chemical deposition and coverage. Using the CFValve™, the potential to "standardize" pressure among knapsack sprayers, regardless of type or brand, has important implications for growers, researchers, and extension agents working to improve control of late blight on potatoes with manually carried equipment. IPM programs must emphasize and aim to make growers understand the importance of the quality over the quantity of chemical spray applications.

As a component of IPM strategies, the CFValve™ makes sprayer calibration possible, is easy to use, and ensures the even distribution of spray solution over the treated area. The flow control achieved with the CFValve™ results in significant chemical savings that will quickly return the cost of a CFValve™ to the farmer and make chemical applications more cost effective for him. The CFValve™ makes the work effort needed to operate a knapsack sprayer easier, and as a result of reduced wear on the pump, has the potential to extend the life of the equipment. As a pressure control device, the CFValve™ has been shown to significantly improve the quality of chemical applications as a result of increased deposition and coverage. In addition, the reduction in potential for spray drift reduces worker exposure to pesticides, and decreases the amount of chemical deposited in the environment.

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