

## PRECISION DISPENSER FOR APPLICATION OF GROWTH REGULATOR IN WHOLESALE NURSERIES

by

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### ABSTRACT

Observations of the application of a plant growth regulator in three Southern California wholesale nurseries drew attention to opportunities in dose precision, ergonomics, and environmental matters. This paper reports on the subsequent development of a semi-automated dispenser for application of BONZI® plant growth regulator for poinsettia plants. Comprised of off-the-shelf components and simple custom structural elements, the dispenser worked satisfactorily with water in initial lab experiments and subsequent field demonstrations. Results indicate that the dispenser can reduce chemical use, reduce the number of unmarketable plants, and reduce known ergonomic risk factors.

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### INTRODUCTION:

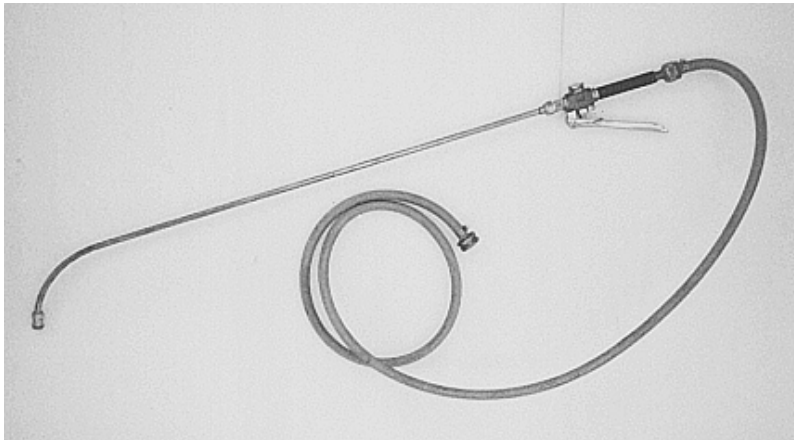
Wholesale nursery growers experience regular losses of poinsettia plants attributed in part to improper application of plant growth regulators. With too much regulator the plant's growth is overly stunted; with an inadequate amount of regulator the plant grows "out" and is not of a compact - and oftentimes more desirable - quality. Anecdotal reports of annual plant losses characterized primarily by problems of overly stunted growth suggest that the chemical solution should be applied in lesser, more exact amounts.

### Current Methods:

Growers profess a strong emphasis on mixing-tank concentration levels but are otherwise hindered by the less-than-exact way of metering the solution to each plant container. With an initial "calibration" and

verification done typically at the nurseries' chemical processing area, subsequent metering is accomplished by squeezing the spray gun trigger for the "calibrated" mental count of four, or the equivalent of about two seconds, to dispense approximately four ounces of solution. Besides being a function of a mental count, the volumetric discharge also depends upon the system pressure, which is generally controlled to about fifty psi (50 psi) at the spray rig discharge port. Regulator, pressure gage, or hose malfunctions can contribute to an ultimately unacceptable cumulative error.

In this study, the plant growth regulator of concern was BONZI®, a Uniroyal Chemical Company product. To properly apply BONZI®, numerous factors must be considered including plant variety, climate, cultural practices, concentration, and volume. The manufacturer recommends that growers perform trials to determine the ideal concentration and solution amount for the particular situation. (Uniroyal Chemical Company, 1991) Though the mixing procedures is understood to be fairly tightly controlled, unfortunately, the commonly-employed spray gun method is not as controlled because it involves individual manual operation of the spray gun for each potted plant.



**Figure 1.** Illustration of typical spray gun, comprised of a Spraying Systems Company #4754 inlet handle, #36 trigger valve, and #6671 extension assembly with curved body. Sample hose shown. Typical length is 150 feet.

The spray gun operated in the process described above does not actually spray, but instead delivers full-flow discharge directly to the surface of growing medium. The method is referred to as the drench method. The common gun observed at the cooperating nurseries is Spraying Systems Company's GunJet® spray gun assembly as shown on the previous page.

Other elements of the existing typical mechanical system include a spray rig with a positive displacement pump, up to several hundred feet of 3/8" 570-psi-rated Spralite hose or equivalent, and a tractor for Power-Take-Off power. Hose and gun connections are heavy-duty brass garden style to facilitate quick changes. Spray rigs are generally configured for dual hose operation to accommodate two independent workers, to maximize use of capital equipment whenever possible.

## Input Resources:

Incorrect application of BONZI® results in an especially untimely loss of input resources because the loss essentially occurs near the completion of the nursery period. Losses include all of the labor required for propagation, transportation, and transplanting, as well as direct chemical costs and land use opportunity costs. For growers whose production is in the 500,000 to 1,000,000-plants range, even a small loss-percentage translates into a significant financial loss in chemicals alone.

Growers are looking even harder to make full, effective use of all resources, especially space, but often have to include notable allowances for expected plant losses in their land-use strategies. Reduced land use efficiency is of rising importance to nursery operators who are feeling the pressure of urban sprawl in Southern California. Rising concern about escalating land values and reduced possibilities for local expansion is being partially manifested by growers' efforts to relocate current and/or expansion facilities to lower cost regions away from the encroaching suburbs.

## Ergonomics:

Another major issue which is beginning to creep into agriculture is ergonomics, or human factors. Work-related musculoskeletal disorders are an increasing concern because of their rising incidence. Meyers, et al., (1996) identified three ergonomic issues of concern in California agricultural work: prolonged stooped postures, lifting and carrying, and repetitive hand work. According to the California Department of Industrial Relations (1991) almost half of all occupational injuries occur in the agricultural production area. In a nearly completed, three-year project focusing on wholesale nurseries, Miles, et al., (1996, 1997) showed persuasive evidence of the impact of the designed intervention tools and strategies on the targeted risk factors for handling potted plants.

A brief ergonomics review of the drenching task drew primary attention to the highly repetitive motions and static postures required to operate the spray wand. The trigger is activated about twenty-five times per minute, with a "valve open" duration of about two seconds plus a momentary "valve off" period during which the wand is moved to the next container. This task is often performed for most of a workday, interrupted only by set-up and clean-up periods, lunch and related breaks, as well as time to relocate the spray rig and to manage the lengthy hoses. This frequency of trigger use is so highly repetitive that it requires a nearly static contraction of the muscles and tendons used in gripping, as suggested by basic research performed by Jonsson (Jonsson,1988). Rodgers' subsequent work suggests that such prolonged contraction interferes with blood flow to and from affected muscles, making it difficult for them to adequately recover from exertion (Rodgers 1997). For this reason, it is believed that circulatory factors are likely contributors to repetitive motions disorders (Rodgers 1997). In this particular spray-wand task, circulation issues revolve about prolonged gripping and extension of the arm, which creates static loading in the muscles and tendons of the hand, forearm, and the shoulder.



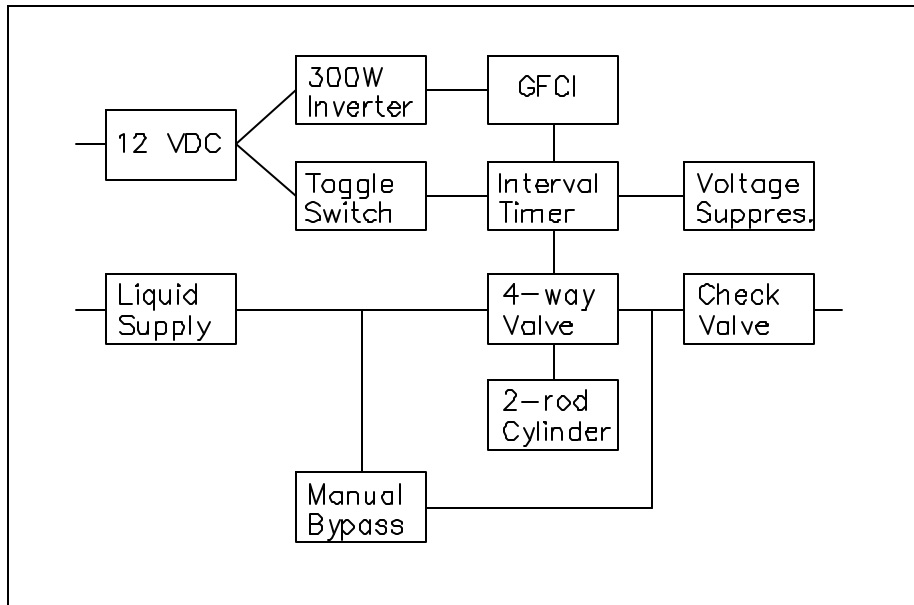
**Figure 2.** Illustration of lab assistant demonstrating potential extension of arm and leg to reach furthest pots in middle of field bed.

When extending the spray wand towards the middle of the growing beds, the task requires severe bending of the worker's wrist in order to locate the wand near the top of the potting mix to avoid missing or splashing. In combination with prolonged static gripping, this increases the risk of work related musculoskeletal problems (Rodgers 1997, Rempel 1997). In addition, the worker must extend one leg back to maintain balance and reduce stress on the back. In such an awkward posture, the worker must then operate the trigger valve with precision, making this job demanding on both bio-mechanical level and the mental level where the squeeze count must occur.

This initial, primarily qualitative, ergonomics analysis, suggests the need to consider simple improvements, such as a pistol-type wand grip and appropriately sized discharge tubes. Of course, a major improvement could be to eliminate the repetitive hand motion through a semi-automated dispenser.

#### DISCUSSION:

The challenge of locating a commercially available, applicable dispenser seemed small, but searches of commercial vendors of dispensing systems uncovered nothing that would meet the existing production requirements. Most available systems were expensive low-volume laboratory units, and others' specifications indicated that cycle rate requirements could not be met because they were of a fill-discharge type. Consideration was given to designing a hand-held flow-meter device, but design efforts instead became focused on assembling a device from off-the-shelf components, as shown in the schematic diagram below.

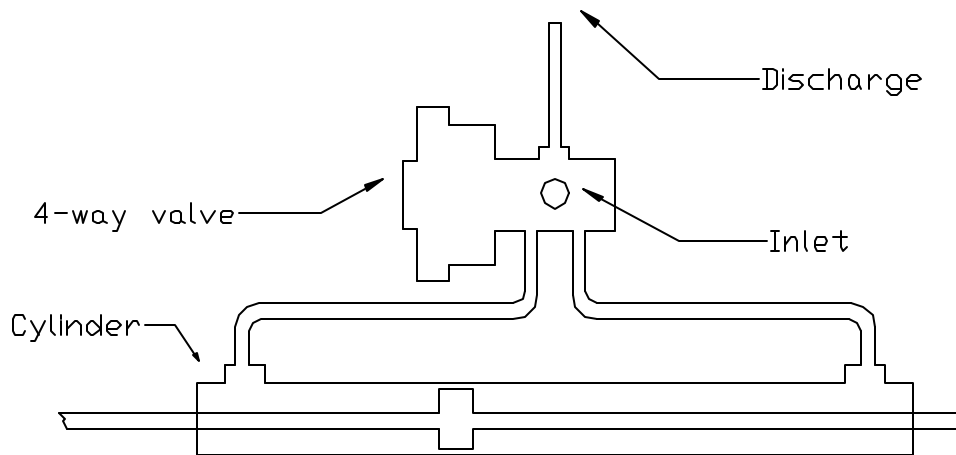


**Figure 3.** Block diagram of dispenser and controls. See Appendix for component information.

#### Cylinder:

The concept of using a double-rod pneumatic cylinder was immediately appealing for its direction-independent, volume to linear-displacement ratio. The cylinder was mounted on a simple steel frame which included a repositionable mechanical stop. This stop could be adjusted to control the volume to stroke ratio. Cylinder diameter and length were sized to create a maximum volumetric displacement which was slightly greater than the largest expected discharge requirement. Consideration, though arbitrary, was given to piston and rod seal life versus stroke to volume sensitivity. This sensitivity is best defined in terms of volume created per expected minimum stop-adjustment of 1/16" or so. Seal life is partially dependent on its cumulative "travel."

Although seal life was expected to be greater with a vertically oriented cylinder, trapped-air considerations strongly suggested a horizontal orientation. However, to avoid all air traps the inlet and outlet of sequential volume elements were "stacked" vertically. (See Figure 3 below.) This would lend itself to start-up air-purge procedure and prevent any but minimal air entrapment.



**Figure 4.** Representation of vertical “stacking” of fluid cavities.

The cylinder element of the system was expected to be the least durable due to the lack of lubrication and the introduction of potential contaminants such as sediment and minerals that would not be filtered by the existing strainers on the spray rig. The design called for an inexpensive, off-the-shelf, “disposable” cylinder. The limiting factor of the proposed dispenser was expected to be the cylinder.

#### Solenoid Valve:

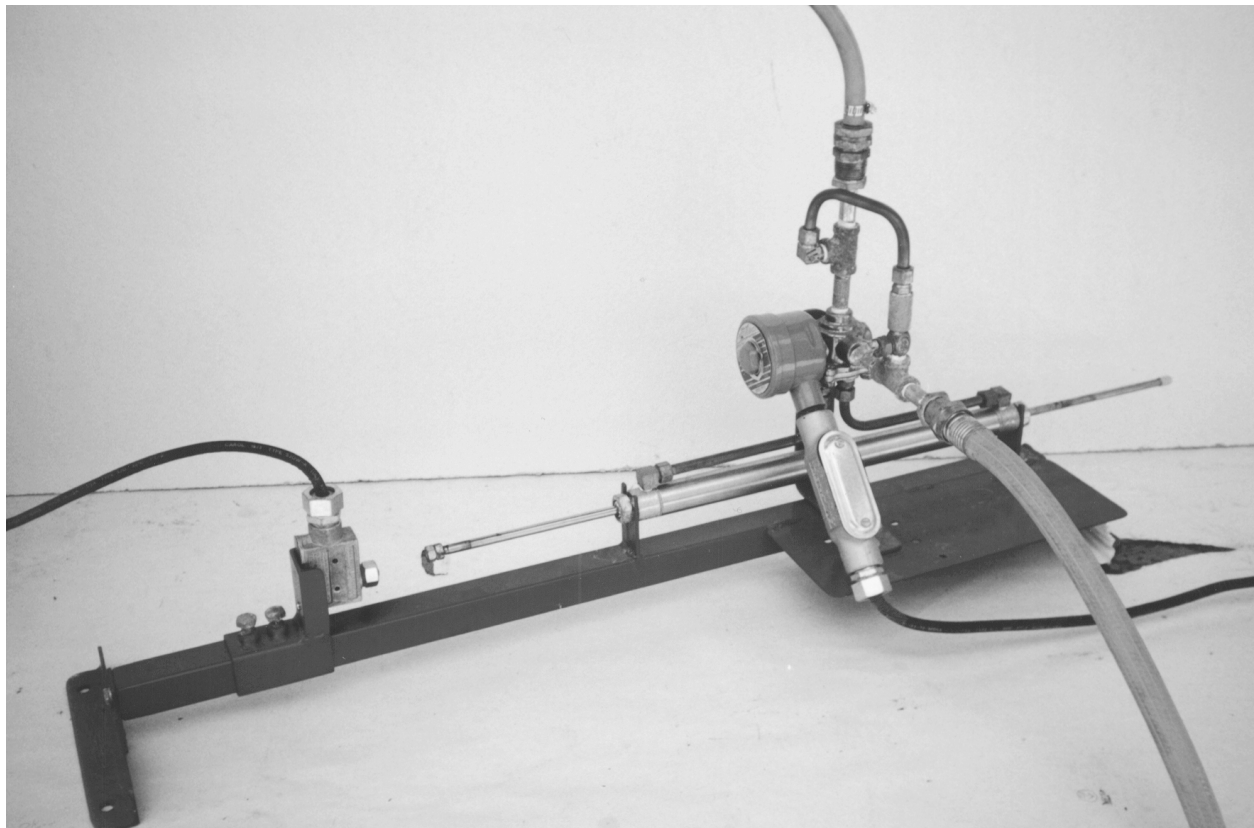
To control fluid flow, a 4-way direct-acting solenoid valve was plumbed to the cylinder ports, the supply line, and the discharge hose. The water medium and the Cv factor dictated by an approximate flow rate demand of two gallons per minute precluded using any of the commonly available low voltage, mini-solenoid valves. The direct-acting model was selected over a pilot-operated model due to the unacceptable volumetric differential created within the solenoid valve by the actuating diaphragm. The four-way valve was selected over a multiple two-way valve configuration due to plumbing and mechanical simplicity considerations. However, the drawback of the selected 4-way valve, though relatively inexpensive and a common stock item, was that it required 120 VAC power, an issue which will be addressed in the next section.

#### Power and Controls:

To control the solenoid, a solid-state interval timer was installed in an enclosed control panel. Individual on- and off-intervals could be set to between zero and ten seconds which provided the required intervals of about two seconds per stroke and a momentary delay prior to the next stroke. The timer

circuit was powered directly from the 12 VDC power supply in the laboratory and from the tractor's 12 VDC battery in the field.

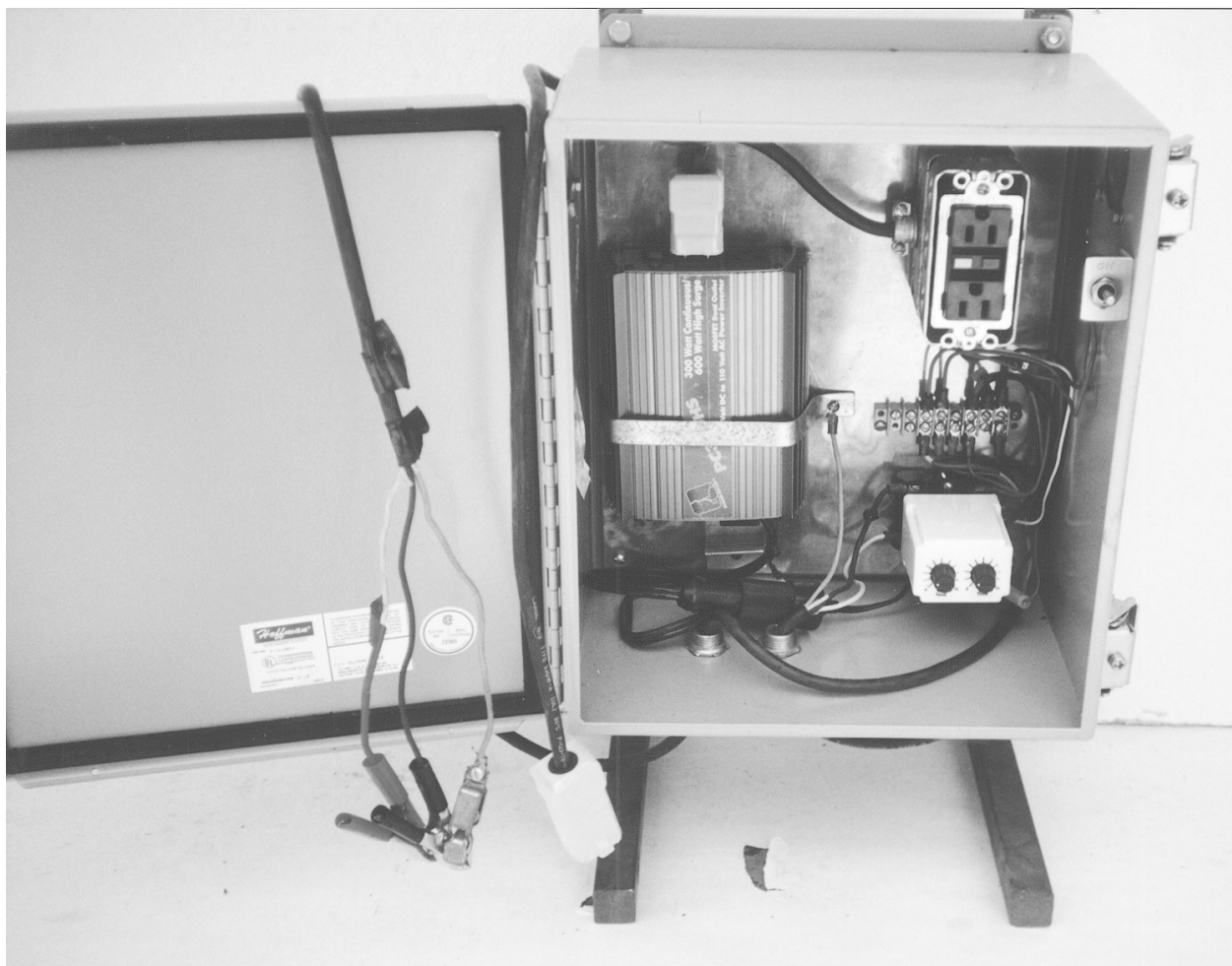
On the other hand, the solenoid power circuit required a 120VAC supply which was supplied by a commercial 300W power inverter typically found in automotive and retail electronics stores. The inverter converted the 12 VDC input supply a modified-sine-wave 120 VAC which was sufficient to the operate the solenoid valve. The output power was wired directly to a commercial-grade ground fault circuit interrupter. Nevertheless, the introduction of high voltage to a portable field environment, such as for which the dispenser is intended, is undesirable if there are any viable options for 12 VDC alternatives. Future design efforts should explore the viability of a multiple, two-way, 12 VDC solenoid valve configuration.



**Figure 5.** Dispenser cylinder assembly in laboratory. (Limit switch for cylinder life-cycle test.)

Purging Bypass- Valve:

Since it was critical that all air be purged from the dispenser and its supply and discharge hoses prior to metering, a bypass valve was installed across the four-way valve between its supply and exhaust ports. Use of this valve occurred in the following steps. With the spray gun in ready mode, the bypass valve was opened long enough to purge any air between the liquid supply source and the dispenser out to the discharge hose, and then it was closed. The dispenser was turned on to operate a number of cycles to purge air from the dispenser itself, and then it was turned off. The bypass was opened again long enough to purge the dispenser air which had been simply moved from the dispenser to the discharge line. For actual field use when chemicals are being used, this purging procedure would require the spray gun to be directed back into the supply tank to prevent waste.



**Figure 6.** Dispenser controls enclosure.

Spring-loaded Check Valve:



The check valve was a very critical and sensitive element of the dispenser system. Its primary purpose was to maintain a full discharge hose between each discharges. The concept was that the check valve would discharge from the hose an amount of fluid that was exactly equivalent to the amount that was “pumped” into the hose by the dispenser, and it would seal the discharge line from leaking for the short moment between discharges. Several sizes of a particular model which appeared would work were tested. The 3/8” model, as opposed to the 1/4” and 1/2” models, produced the least discharge spray and post-discharge residual drip.

An important consideration for the check valve was its cracking pressure, though the specifications indicated that the standard was the only one available. The cracking pressure rating was 1 to 2-1/2 psi. The potential problem in this situation was leakage during hose handling. For instance, when the hose was strongly jerked along the ground, the physical effect of this action upon the hose caused a deformation which forced some fluid out through the check valve. Relatively ginger handling of the hose did not cause any unwanted discharge. Nevertheless, this is an important consideration for future work on and implementation of the dispenser.

#### Operation:

An important operational question of the dispenser was how to temporarily halt the dispenser for any reason whatsoever. It was of course impossible to rush back to the control box to turn off the timer. Instead part of the spray gun included a manual valve which would stop flow to the check valve. Even though the interval timer and solenoid valve continued to operate, the dispenser cylinder stopped traveling back and forth due to the incompressibility of the fluid.

Restarting the operation, on the other hand, proved more difficult. The manual valve had to be opened at particularly the right moment to realize a full discharge through the system. Consideration was subsequently given to installing a light at the control panel which would flash every other stroke to allow for adequate timing to open the manual valve and continue operation.

#### Cost:

Cumulative materials cost of the main components and the miscellaneous fitting and adapters was approximated to about seven hundred dollars. Quite importantly, all main components that could fail were readily available in vendor stock. There were also of course costs - not addressed here - associated with fabrication, wiring, and assembly.

#### System Life-cycle Test:

The primary test for the dispenser was a life-cycle test of the cylinder. The test was conducted with available laboratory water spigot pressure of between 60 and 70 psi, about what is typically used on the existing spray rigs. The laboratory test used a seven foot sample length of proper hose whereas field conditions typically require a length of 150 feet. The spray gun used in the test was a simple machined

grip with a ball valve at the inlet, a length of 3/8" copper tube at the outlet, and the 3/8" check valve at the end of the copper tube.

Water quality references were obtained from the annual campus well tests. The values provided by Environmental Health & Safety Department for the past year were as follows.

For 5 deep wells:		min	max	
Total Dissolved Solids	310	340		mg/l
Calcium		12	23	mg/l

The laboratory life-cycle test showed that the cylinder remained accurate within 1% of calibrated volume through 300,000 discharges, after which the error increased both in comparison to calibrated volume and in discharge difference between the two sides of the cylinder. At approximately the 300,000 cycle mark a slight gurgling sound could be detected when the piston traveled in one of the directions. Also at this time a little bit of moisture was building up at the rod seals with an occasional drip from the seal. The gradual increase in discharge differential from one side to the other grew until it was just less than 5%, though discharge in one of the directions did not change more than 3% based on periodic sample measurements. By this time the external leak at one of the rod seals had increased to about one drip every few minutes. Then, at around the 675,000<sup>th</sup> stroke and about 5% piston seal leakage, the questionable rod seal failed and the test was stopped.

By the time the cylinder failed, the check valve was showing a slightly more dispersed but not seemingly unacceptable discharge pattern. However, more importantly the check valve did produce a noticeable post-discharge drip of two or three drops.

#### CONCLUSION:

The semi-automated precision dispenser developed in this initial study showed that a pneumatic cylinder could be used as an expendable element in a system to meter precise amounts of water for a significant number of strokes before failing. This type of a system holds promise to be capable of precise dispensing of plant growth regulating solutions, such as Uniroyal Chemical Company's BONZI®. Semi-automated dispensing of this typically four ppm solution would improve chemical utilization, reduce unmarketable plants, reduce land-use requirements, and reduce known ergonomic risk factors. More work should be done on the solenoid in terms of voltage, on the check valve in terms of cracking pressure, and on the cylinder itself. Perhaps a different size cylinder could be used. Finally, a reassuring aspect of this work - and a reason to continue it - was the interest and motivation of potential users to proceed with self-guided testing on portions of future crops.

APPENDIX:

Major Components list:

1 ea	ASCO 8342C1	Solenoid valve, 120 VAC, 4-way, direct acting
1 ea	Newark 92F3377	Recycling timer, 12VDC, 12DA/ADFA)
1 ea	Newark 23N3600	Module socket, RS8-B
1 ea	Shrader 1.06KDXSR12.00	Pneumatic cylinder, double-acting, double-rod, bumpers
1 ea	Ryan Herco 5162-003	Spring-loaded check valve, Kynar
1 ea	Hoffman A-14128CH	Steel electrical enclosure
1 ea	Pass & Seymour 1591-F	Ground Fault Circuit Interrupter
1 ea	Whistler PP300AC	300W High Surge Power Inverter (12 VDC to 115 VAC)

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