VARIABLE RATE APPLICATION EQUIPMENT FOR PRECISION FARMING

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Abstract

This paper provides a brief overview of precision farming, followed by an overview of the main components of variable rate equipment, then concludes with a summary of the current commercially available equipment for variable rate application of seeds and chemicals. The equipment reviewed includes: computer/controllers, liquid sprayers, granular fertilizer applicators, air sprayers and spreaders, and drills and planters.

Introduction

Precision farming is a farming system concept which involves the development and adoption of knowledge-based technical management systems with the main goal of optimizing profit. This management system will enable micro-management concepts, that is, the ability to appropriately manage every field operation at each location in the field, if it is technically and economically advantageous to manage at that level. The system will likely include the ability to vary or tailor the rate of application of all inputs such as tillage, seeds, weed, insect and disease control, cultivation and irrigation.

It will be possible to implement precision farming at many different levels. In its most extensive form, it will include precise micro-management of every step of the farming process. It is expected that the advisability of micro-management will be dependent upon many factors, such as soil type, crop, seasonal weather, and other factors. For example, in a dry year, it may be possible to control insects by spraying only small areas where the insects are known to exist; in a wet year, it may be advisable to uniformly spray the whole field.

Technically, one important aspect of the development of precision farming concepts is the development of the hardware and software necessary to vary the rate of the application of agricultural inputs. A number of research projects have been conducted in this area, and several companies have been developing variable rate application equipment in recent years. The objective of this paper is to provide a brief overview of precision farming systems, then outline the main components which are usually found in variable rate application equipment, followed by a review of the commercially available equipment on the market today.

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Precision Farming System Overview

An overview of the precision farming system of the future is depicted in Figure 1. The brain of the system is a geographic information system (GIS), which will form the knowledge base and decision making parts of the precision farming system. The technical and economic decisions related to the farming operation will be governed by this knowledge based GIS. A GIS will be made up of layers of related information, and the GIS will allow a quantitative study of the relationships between the layers. For example, the GIS may contain the following layers: (1) field topography, (2) soil types, (3) surface drainage, (4) sub-surface drainage, (5) soil testing results, (6) rainfall, (7) irrigation, (8) actual chemical application rates, and (9) yield. Some of these layers will be entered once; some will be entered annually or even more frequently. The GIS will then allow a study of the relationship between these layers of information to determine cause and effect and to base decisions upon this knowledge.

As indicated in Figure 1, each field operation may include variable rate technology. Tillage depth may be varied according to field location; for example, subsoiling depth may be dependent on field location. Seeding rates may vary according to field location, which may depend on factors such as topography and soil type. Fertilizer application rates may vary in relationship to factors such as soil type and the results from either real time or pre-application testing. Application of insecticides may be dependent on insect location from either scouting reports or from aerial imaging. In like manner, the application of all inputs to the crop production process may vary with field location.

Overview of The Components of Variable Rate Application Equipment

The main components which make up a variable rate application system are shown in Figure 2. Not all systems will necessarily contain all of the components shown. As variable rate technology develops, other system components may be included.

The central component of variable rate application equipment is the computer/controller. This device receives information from several sources which will in turn be used to control the application equipment. The controller may receive information from the application equipment and other sensors to maintain a database on the actual application rate as a function of field position.

A key component for all precision farming operations is the technology to determine the instantaneous position of

equipment as it operates in the field, and to provide this information in a computer compatible format. The technology which has rapidly gained acceptance as the optimum system is the Global Positioning System (GPS). A stand-alone GPS receiver can have instantaneous errors as high as 100 m, which is unacceptable for precision farming. Fortunately, several systems to calculate what is known as "differential corrections" have been designed, which can allow the GPS system on a farm vehicle to achieve position accuracies in three basic accuracy ranges: (1) 2-5 meters, (2) sub-meter, or (3) in the sub-decimeter range, depending on the technologies used. These maximum error figures relate to horizontal position, and vertical position (elevation) error is usually 1.5-5 times the horizontal position error. Most precision farming operations do not require vertical position information; the main application requiring vertical as well as horizontal information is to develop topographic maps. Most precision farming operations will require real-time differential corrections so that vehicle position information will be accurate when the vehicle is operating in the field. For precision farming applications, the GPS positioning technology should be thought of as RT-DGPS, that is, the farmer should always be using real-time differential corrections to minimize position error.

Information contained in the geographic information system related to a specific field operation is downloaded to the system computer before field operations commence. The computer/controller will continuously control variable application rates based upon knowledge gained both from the geographic information system, from a knowledge of field location as provided by RT-DGPS, and perhaps from real time sensors. For example, assume that the desired fertilizer application rate is known to be a function of results from soil analysis tests, field location, and crop. The soil analysis test results as a function of field location would be entered into the GIS and downloaded to the computer/controller of the fertilizer applicator. If one crop is being grown in the field being fertilized, then the operator may simply enter the crop from the computer/controller keyboard. However, if two crops are grown in alternating strips, this information would be entered into the GIS as a function of field position, then also downloaded to the variable rate application (VRA) computer/controller. When the equipment is operating in the field, the VRA computer/controller will be receiving RT- DGPS receiver position information and will match required application rate and crop as a function of field location to control the applicator equipment. It may also be possible to have a real time soil sensor which will provide information on-the-fly about fertilizer application rate needed, rather than using pre-application soil sampling/ analysis techniques.

The application equipment may also have sensors which provide quantitative information on the actual application rates. This information, along with RT-DGPS position, can be recorded to maintain a historical record of application rates. This historical information may allow the farmer to analyze cause and effect in the precision farming system, and perhaps can influence future decision making processes implemented in the computer/controller. For example, assuming that sufficient information has been gathered over several years, the farmer may have historical records on the effect of all of the inputs to his system for a specific field, including the crop yield. The GIS would then allow an analysis of cause and effect, based upon many factors, and allow fine-tuning of chemical application rates in subsequent seasons.

Eventually the RT-DGPS system may also be used for vehicle guidance. Most farm vehicle guidance systems today are visual prompting systems for the vehicle operator which can establish accurate vehicle position for application swaths. In the future, the guidance system may automatically guide the application vehicle.

A VR Sprayer Scenario

To provide a specific illustration, consider the diagram of a relatively simple liquid sprayer VRA system as depicted in Figure 3. The following discussion is provided as one scenario for each component, but there may be alternative sensors and methods of control. A radar based ground speed sensor would be used to provide true ground speed to the computer/controller since application rate is a function of speed. This system depicts the use of a direct injection sprayer, which is the direction in which sprayer technology is proceeding. With this type of sprayer, the operator does not mix the chemical(s) in the main tank, rather, the chemical(s) remains in a container, where it may be pumped as needed into an injector where the chemical(s) is automatically mixed with water on-the-fly. There are many advantages to this system as compared with tank-mixing, such as safety, managing mixed chemicals, and automation. The injector pump may be designed to provide precise control of the injection rate of the chemical concentrate to the injector.

The water tank may have a level sensor which will allow the computer/ controller to determine the amount of water remaining in the tank in gallons. The total flow rate of the fluid going to the boom(s) will be controlled by the flow control valve, which in turn is controlled by the computer/controller. The actual total fluid flow rate will be monitored by the fluid flow rate sensor, and this information will be used by the computer/controller for fine adjustments in the flow control valve. The fluid flow rate and the vehicle position will be continuously recorded in the computer as the vehicle sprays to provide a historical record for the GIS about where and how much chemical was dispensed. The boom valve will be used to turn the boom on or off to provide fast accurate control of the application area.

To further illustrate this system, assume that you may be in the middle of the cotton season, and the cotton is being scouted on a normal cycle for insects. When the scout goes to the field, he/she may carry a portable GPS unit. When an insect infestation is identified, the scout could walk around each infested area with the GPS unit, thereby recording the location of the areas of infestation. Assume that the scout finds two such infested areas. The scout would inform the farmer that infested areas were located, and the farmer would download the map which shows the infested areas. The map would include not only the insect found, but the estimated insect density.

The farmer would then enter this infestation map into his existing GIS for that field. The GIS software would examine the data as related to appropriate information such as current and forecast weather conditions, crop age, and the history of this crop, including other chemical applications. The GIS software would be designed to model the growth of the crop and the expected effect of this insect on crop yield. The objective would be to determine the cost effectiveness of spraying with several possible scenarios: (1) uniform spraying of the entire field, (2) spraying of the infected areas only, or (3) no spraying. Assume that this intelligent system indicates that the farmer should just spray the infected areas. The farmer would then download several important maps to the computer/controller on the spray vehicle. The GIS information would likely consist of several maps: (1) a map giving the coordinates of the field boundaries, which may exclude areas within the outer boundary (waterways, roads, etc.), (2) a map giving the coordinates of the crop boundaries, (3) a map giving the location of each crop row, and (4) a map giving the location of the infected areas, and the name of the insect. It will be assumed that the insecticide application rate may be varied within each infected area. Information on the total amount of water and chemical concentrate required for the spot spraying would also be downloaded to the computer/controller.

When the vehicle operator starts, the software in the computer/controller will examine the data downloaded from the GIS. The computer display will provide instructions about which chemical concentrate to load onto the vehicle, and how much concentrate and water are needed. The operator will then place the chemical concentrate tank onto the vehicle and hook it to the computer/controller. The computer will read information from a microchip on the concentrate tank and will check to be sure that this is the correct chemical for this crop and insect, along with determining the appropriate application rate. Also, the computer will check a concentrate tank sensor to be sure that the concentrate tank has sufficient chemical for the operation. To load the water tank, the operator will attach a water hose to the tank, which will have a valve on the inlet line controlled by the computer/controller. If the tank has insufficient water, the inlet valve will be opened. When the computer senses that the tank has sufficient water for the operation, the inlet valve will be closed.

If the vehicle operator is spraying many fields over a wide area, the system can incorporate a road map of the area which can be displayed in the cab. The RT-DGPS system will be used to display the actual vehicle location on the map, and the mapping system will be used to determine the optimum route to the field. When the vehicle arrives at the field, the display system will automatically change scale to show a map of the field, including the location of the infested areas. The display will provide directional information to the operator indicating which rows the operator should drive down to spray. The spray booms will be automatically extended when the RT-DPGS information says that the vehicle is within the field. The operator will proceed down the first row to which he has been directed. As the vehicle approaches the boundary of the infested area, the main pump will be automatically started, the boom valve will be opened, and the sprayer will begin to dispense water. The injector pump will begin at the appropriate time, depending on the lag time for the concentrate to enter the injector and arrive at the nozzle. As the vehicle approaches the boundary where the spray application will stop, the injector pump will stop to allow the appropriate time for the chemical to clear out of the boom. The boom valve will be closed when the vehicle reaches the other boundary of the infested area.

This process will continue until the operator has sprayed the infested areas. Note that it will be necessary to only drive selected rows to cover the infested areas, not the entire area.

When the field is finished, the operator will download the information on the actual rates applied as a function of field location. This data will be entered into the GIS for use in further operations as needed. This data may also be useful for further studies of the effectiveness of this chemical, and may be used in subsequent years to modify decisions.

Variable Ra Equipment te Application

The appendix of this paper contains a tabular summary of currently available variable rate application equipment, and information on how to contact these companies. Company names reported herein were found through magazine ads, scientific publications and word of mouth. The authors do not wish this report to be viewed as a complete review of all the possible companies working in the precision farming arena, as the concentration of this paper is only on the VRA aspects. Because the VRA technology is a rapidly developing field, it was found that some companies were unwilling to divulge engineering details related to their equipment because of patent rights.

For each company only the equipment or systems that are directly related to VRA are listed. We apologize to any companies producing VRA equipment who were inadvertently excluded from this review. We invite any companies not included herein to forward technical information on their VRA equipment for inclusion in future review publications of this nature. The mention of brand names is for information only and does not imply endorsement by the University of Georgia.

Summary

In this paper the precision farming system of the future was briefly outlined. The brain of the system is a geographic information system which will enable knowledge-based farming decisions to optimize net profit. An important aspect of the technology is the ability to vary the rate of application of all inputs, that is, to tailor or prescribe the application to various sites throughout each field, including tillage, fertilizer and lime application, planting, cultivation, and spraying. The components usually found in variable rate application equipment were outlined and discussed in some detail. The paper appendix contains two summary tables which provide information on most companies involved in producing variable rate application equipment.

Most of the commercial ventures to date have focused on the variable rate equipment for application of liquid and granular materials. There remain many unanswered questions about how to implement this technology. It was pointed out that the GIS is the brain of the system, but this aspect of the technology is still in the infancy stage. A critical aspect of the electronic technologies is standardization, ranging from physical connections which can withstand the farming environment, to standardization of data format. It will be critical to develop the technologies to make them simple to use and user friendly, as well as economical. Much technical development work remains before the precision farming system of the future can be implemented. In the final analysis, it must be shown that precision farming pays- particularly economically, environmentally, and from the viewpoint of the conservation of our natural resources.

For more information on precision farming, contact the University of Georgia precision farming web site at: http://www.bae.uga.edu/dept/research/precision/index.html. This paper and the attached review, links to other similar web sites, and information on precision farming are provided at this site.

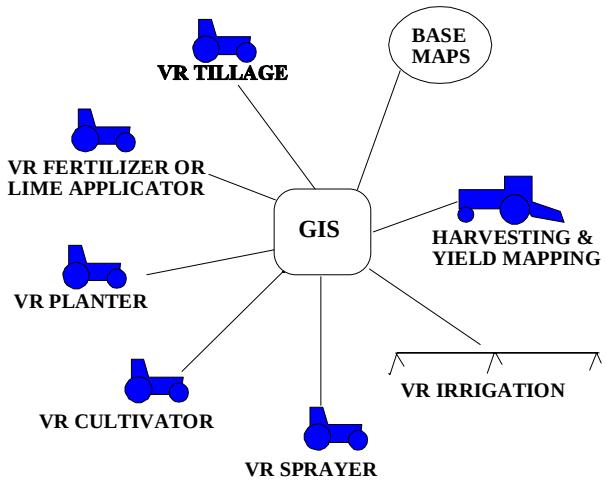

Figure 1. Overview of the Precision Farming System
Note 1: Each line represents a two way flow of information
Note 2: V.R. means "variable rate"
Note 3: Each field operation will include real time sensors, such as sensors for position, moisture, nitrogen, flow rate, etc.

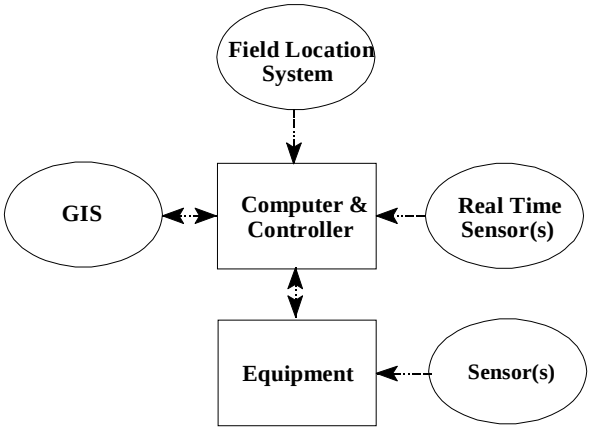

Figure 2. General Overview of Variable Rate Equipment.

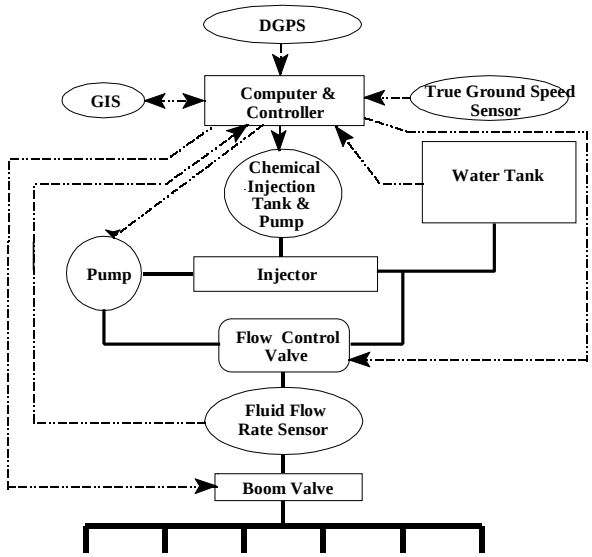

Figure 3. General Components of a Variable Rate Sprayer

Table 1: **List of Equipment that has been used for Variable Rate Application, by Company Name**

Company: Ag-Chem

Product	Features
Soilection	Dry or Wet System for fertilizer, herbicides and seeding System incorporates: Soil testing & mapping Mapping yield goals On the go blending and application Maps entered into computer for application rates SOIL TEQ (a subsidiary of Ag-Chem) converts info to maps used by the Falcon controller System includes: Falcon Controller and software Product Metering Controls Ground speed sensor Navigation system Feedback sensors
Falcon	Controller for Soilection Used with: IBM, Windows, and SOIL TEQ software
Terra-Gator	Hi-floatation applicator Fertilizer, chemicals, micro nutrients and seed application in 1 pass.
Air Spreader	Variable Rate Application Radar controlled accuracy (DICKEY-john) Line-drive tandem pump Vertical and horizontal mixing for increased homogeneity Soilection, Raven SCS or DICKEY-john controllers Options: granular metering system liquid impregnation system liquid application system
Liquid Sys.	Independent, retractable boom system Pressure throttling Precise nozzle pressure control Variable application rates - Soilection 3 nozzle outlet system allows uniform distribution

Company: Automatic Equipment Mfg. Co.

Product	Features
Sprayers:	
MB50H	PTO driven sprayer For: pasture, range, trees, low shrubs Insecticide or Herbicide application Roller pump
MB50SK	Engine driven sprayer, mounts in pickup truck Electric volute rotation 50 or 200 gallon tanks Optional Micronizer spray heads Roller pump
MC-50R	PTO mounted sprayer For: broadcast, row, orchards, groves, pasture, range or vegetable spraying Micronizer spray head Premixing of chemicals Sparge agitation Hydraulic rotation Electric solenoid Roller pump
MC-60C	Ideal for Orchards Centrifugal pump Micronizer spray head Premixing of chemicals Sparge agitation Hydraulic rotation Electric solenoid
Applicators	Liquid or suspendable inoculates Precision application through pressure control Five nozzle tips Pressure relief valve Variable speed pump pressures Pressure gauge Motor driven Duplex-diagphram pumps

Company: BEE Ag-Electronics, Inc

Product	Features
Sprayer Plus	Includes: Meter head and mounting Power, Tractor and Implement harnesses Controller module Wheel magnetic sensor Flow sensor and plumbing Programmable and manual rate control Programmable nozzles and nozzle spacing

	Automatic adjustment for number of booms
	Nonvolatile battery

Company: Capstan/RHS

Product	Features
Synchro	Sprayer control technology with solenoid valves
	Retrofits any conventional sprayer
	Independent control of:
	Flow
	Droplet size
	Band width (90 degree rotation)
	Boom output
	Controlled with Raven, Micro-Trak or Mid-Tech
	GPS interface

Company: Chandler Equipment

Product	Features
Models FT-55 and FT-LH	Truck mounted fertilizer and lime spreaders
	Options:
	Pressure wheel drive with hydraulic spinners
	Full Hydraulic Drive
	PTO Drive
	Two sets of sprockets - Lo-Med and Med-Hi application
	DICKEY-john or Mid-Tech ARC 6000 controllers used

Company: Concord

Product	Features
Detect-Spray	Herbicide sprayer
	Reflectance based sensors to detect weeds
Air System 2400	Tow-between air system
	Benefits:
	Reduce side drift on hills
	Eliminates tracks behind drill
	Weight transfer to tractor drawbar
	Auger load and unload from tank
	Ground driven metering cup
	Monitor available
	Remote on/off switch
	Static Rate check
Applicators	Liquid or suspendable inoculates
	Precision application through pressure control
	Five nozzle tips
	Pressure relief valve
	Variable speed pump pressures
	Pressure gauge
	Motor driven Duplex-diagphram pumps
TerraNova VRS	A comprehensive VRT system
	The system is composed of:
	Any Concord air applicator
	PC laptop running DOS
	TerraNova software
	Any Micro-Trak, Raven, or Ag-Chem controller
	Any GPS receiver at NMEA-0183 GPGGA or GPVTG data strings
	Deep banded seed and fertilization in 1 pass
	Variable application rate
	Fertilization: solid, liquid, anhydrous ammonia
Air Drill System	A comprehensive VRT system
	The system is composed of:
	Concord air till drill
	Two tanks with metering gates
	PC with CADS software
	Microprocessor
	GPS receiver
	Application maps built separately
	Linear actuators control metering gates, microprocessor controlled
	In cab real-time display of field

Company: Del Norte

Product	Features
LandNav	Control System for parallel swathing
	Fertilizer and pesticide application
	System includes:
	GMU - DGPS system (accuracy to 30cm): Receiver, Processor board, Interface board, Power Supply
	CDU - (Central control and display unit) keypad, LCD display, connection to GMU unit
	Differential Radio Receiver - data rates @ 4500 baud transmits data required by RTK/OTF solution
	Guidance lightbar
	LandNav software

Company: DICKEY-john

Product	Features
DjCCS 100 & DjCMS 100	Work together to provide sprayer control and monitoring
DjCCS100	Liquid Sprayer Control System
	Can be used for anhydrous ammonia and spreader
	Includes:
	Control Console
	Switch Module
	Control Valve
	Pressure Transducer
	Ground Speed Sensor
	Pressure based system
	Variable Rate Application
DjCMS 100	Custom Monitoring System
	Displays: ground speed, area, productivity, application rates, sensor outputs
	Used with DJCCS 100
PCS	Precision Control Systems
	Controller for liquid or granular application of: fertilizer, pesticides, herbicides and NH3
	Data capture
	Multi-channel operation
	Externally located master control unit

Company: Gallenberg Equipment, Inc.

Product	Features
Airglide Sprayer	Wet or Air application boom
	Raven or Midwest TASC controllers optional

Company: Gandy Company Manufacturers

Product	Features
Speed-Comp	Monitors speed indicators (radar, wheel sensors)
Controller	Adjusts metering system for on-the-go changes
	Used with Orbit-Air system
Orbit-Air	Application of fertilizer, chemicals or seed
	Mounts on: Field cultivators, chisel plows, planters, row cultivators, trailers, high clearance units, and other delivery systems
	Venturi chamber outlets, individually controlled
	Can use Raven control system and GPS
Zero-Max	Maintains constant rate of metering system
Control	Works with ground driven or constant speed electronic metering systems
	Used with Orbit-Air

Company: Hagie

Product	Features
Sprayer 284	Dry type booms
	Variable row spacing
	Solenoid solution valves
	Variable speed control agitation and pumps
Sprayer 254	Dry type booms
	Variable row spacing
	Solenoid solution valves
	Variable speed control agitation and pumps
	Raven 440 or Trak-Net TNC 1700 monitor option

Company: Hiniker

Product	Features
8150 Control	Variable Rate Application Control
System	For NH3, pesticides, and liquid fertilizers
	Sprayer applications: Boom, Row Crop, Incorporating, Orchard and Vineyard, High Clearance, and Band sprayers
	Includes: Control console
	In-line flow meter
	Hub plate distance sensor
	Stainless steel control valve & servo valve
	Remote run/hold switch
	Apply at two preset rates
	Manual override, for remote pressure adjustments or setting a third application rate while spraying.
	Programmable valve response
	Controls up to three booms
	Optional: Radar Interface
	Flowmeters and Servo valves for special (high capacity, low volume) applications
NH3 Control	Includes:
and Monitor	Spray command console
System	Auto-FACTS console & Computer-FACTS console
(HAAMS)	Heat Exchanger
	Ball valve to NH3 Tank
	Starflow valve & electro servo valve
	Tee and Hydrostatic valve
	Electric/Hydraulic or rope operated shutoff valve

Company: Illini FS

Product	Features
Green Plan	Precision Farming Technology Link
	Soil Testing
	Fertilizer, Chemical & Seed Recommendations
	Crop Scouting
	Crop Records
	Crop Production Economics

Company: Kinze Mfg, INC.

Product	Features
Rate Reducing	Two speed mechanical clutch
Clutch	Low cost
	Variable rates (2)
	GPS connection
	12 V DC required

Company: Micro-Trak

Product	Features
Trak-Net	Control and Monitoring system for all Micro-Trak Trak and TN systems
	Ties all M-T equipment together for Precision Farming
	Computer system, includes all of the following
	Soon to be operational are Tru-Trak and Seed-Trak
Data-Trak	Tracks and records all field data on a memory card
	For any of the Trak-Net systems
	Includes: Console
	Power and communications module
	GPS receiver
	Removable memory card
	Data card reader
	Computer running mapping software
	TNm1100 data-logger
Grain-Trak	Yield tracking
	Moisture measurement
	Permanent database memory storage
Soil-Trak	Auto navigation for soil sampling
	Has four modes of sampling
Nitro-Trak	Use with Continental meter matrics: B-9500, C-4100, C-2500
	Monitors ground speed & temperature
	Adjusts meter setting to maintain application rate
	Includes: Control console & mounting
	Control kit for specific meter matric values
	Power and Control Cables
	Magnetic speed sensor
TN-7000	Automatic Sprayer Controller
	Includes: TNb1000 distance/area monitoring console

	TNc1700 application control console
	Battery
	Magnetic speed sensor
	Servo control module
	Servo valve
	Flowmeter and pressure sensor
	Control methods can be pressure based, flow based or a hybrid combination of flow/pressure
	Controls one fluid, but can be expanded
	Manual override for spot spraying
NH3 Kit	Add to M-T sprayer system
	Includes:
	Heat Exchanger/Condensor
	Flowmeter
	Electric servo valve
	K-Z electric shutoff valve
	Hardware, mounting and wiring harness
	Strainer
	Auto compensates for changes in speed, temperature and pressure

Company: Midwest Technologies, Inc.

Product	Features
TASC 6000 series	All systems include:
	Simultaneous or Individual operation and control
	Application rates:
	Controlled by Hydro Servo Valves
	Preprogrammed by channel
	Changed during operation by %
	In line flow meter and rate sensor
	GPS/GIS datalink available
	Radar connection
	Controls up to nine boom sections
	Externally mounted control switches:
	Master switch
	Ground speed override switch
	Open/close switch for TASC
	Software available for data links
TASC 6200 and 6500	Granular or granular/sprayer applications
	Both use
	An in-line flowmeter for booms
	A rate sensor for granular product
TASC 6200	Controls conveyor for granular or wet boom application (two channels)
TASC 6500	Five control channels for additional control of:
	DC motor on Granular Coapplication bins
	Liquid Injection Pumps
TASC 6000, 6300 & 6600	For sprayer applications; flow control only
	All include:
	Auto-Range flow control valve
	Mid-Tech tanks
	Printer
	Peristaltic metering pumps
	Systems can monitor up to nine boom sections
TASC 6300	Three control channels
	Chemical injection control
TASC 6600	Six control channels
	Chemical injection control
TASC 6000	One control channel
ARC 6000	Automatic Rate Control
	Up to nine boom response
	Liquid or granular applications
	On-the-go rate changes
	Programmable valve response
	No data link available
	Includes:
	Auto-Range flow control valve
	Hydraulic servo control valve (for granular)
	Electronic flow meter
ISC 3500	Injection control system
	Includes:
	Control console
	Peristaltic metering pumps
	Two Micro-Tanks,
	Electronic speed sensor
	On-the-go rate changes
	Isolated system, so no chemical contact necessitated

Company: Progressive Farm Products

Product	Features
	Progressive uses Mid-Tech ISC 3500 controllers
Spra-Kaddy	Pull between, three point hitch
	Optional:
	Pumps
	Controls
	Plumbing
	Dry fertilizer air system:
	Used with Spra-Kaddy
	Quick-change sprockets for rate changes
Auto-Kaddy	Converts mounted implement to pull-type
	Can carry tanks for liquid fertilization
	Valves:
	For open, center and closed center tractors
	Flow control and relief valves
	Hydraulic cylinders for rear axle guidance
	Console:
	Manual range adjustment
	Shows speed, acres/hr and distance
	Needle scale gives left/right orientation of axle
Twin-Frame Sprayers	Booms can hydraulically fold
	Three boom electric control
	Includes:
	Hydraulic Pump
	Tanks
	Optional:
	PTO pumps
	Injection system
SPOT-SHOT	SEEING-EYE
	Sprays only when a weed is there
	Radiance based vision system
	For:
	Broadcast application

Manual application
Individual units available

Company: Raven

Product	Features
SCS 460, 440 & 330	Sprayer Control Systems For Agricultural, roadside, or turf spraying
SCS 440	Two application rates, programmable Three or six boom section control (separate consoles) Manual override for spot spraying Includes: Radar, wheel drive, or drive shaft speed sensors On-off valves Butterfly, ball or hydraulic valve Choice from a variety of flow meters
SCS 330	Constant rate application Control of up to three boom sections Manual increase/decrease with hand spot application Includes: Control Console & control cable RFM 15 flow meter Auto control butterfly valve Wheel drive speed sensor
SCS 460	Six boom system, Used with existing boom and switches Two application rates Includes: Control console & cables Flow meter Control Valve Speed sensor
SCS 750 & 700	Chemical Injection Systems Nonvolatile, 10 year memory Hand sprayer attachments Includes: (either/or) Injection Assembly - attaches to tanks with agitators Injection Modules - pump, motor control and tank preassembled Attachments: Piston pumps: positive displacement In-line mixer or mechanical agitator Radar speed sensor Regulating valves Flow meters
SCS 700	Two different chemicals and application rates Electric or Hydraulic valves
SCS 750	Controls up to five different chemicals or, four chemicals and a carrier fluid Controls Liquid, Granular or Hydraulic Systems simultaneously
Flow Max 810	Automatic Batch Control Console For deep root tree feeding application Programmable batch volume Nonvolatile memory
Low pressure	Less than 250 psi Includes: Control console Motorized boom valve RFM 15 Flow Meter Wireless remote control
High pressure	Less than 650 psi Includes: Control console Steel high pressure on/off valve RFM 55A Flow meter
ACCU-FLOW	Anhydrous ammonia application Raven SCS 330 or 440 control Includes: ACCU-FLOW super cooler Strainer & magnet assembly Flow meter Pressure gauge Temperature gauge Shut off valve

Company: Rawson Control Systems, Inc

Product	Features
ACCU-PLANT	Hydraulic drive for planting and drilling Includes: Processor Radar speed sensor Hydraulic Drive Pressure gauge Planting or fertilizing/pesticide applications Programmable rates from 1 to 1000's lbs application Seeding at 1000 to million seed increments Ten year processor memory Drilling, air spread, planting or dry fertilizer application

Company: Remcor, Inc.

Product	Features
RC-1B Systems	Sprayer control systems Available with or without solenoid valves Toggle-type Boom and Pressure Regulator switches Four or five boom control Four or five solenoid valve control Includes: Control console Regulator & master switches Cab & sprayer harnesses Solenoid valve (if operator does not already have) Pressure gauge & high pressure gauge line Valve mounting bracket Power cord and fuse
RC-10N Systems	Remote control systems Controls one boom shutoff valve System comes with or without solenoid valve Includes: Console

	Regulator & on-off boom switches
	Pressure gauge
	Power cord and fuse holder
	Sprayer harness with high pressure gauge tubing
	1560 pressure regulator
Three-point	Includes:
Sprayers	Plumbing with Anti-Vortex Fitting and agitators
	Line strainers with cutoff
	Eight-way manifold with pressure gauge
	Pressure relief valves
	Optional:
	Six roller pump and PTO connector
	Boomless nozzle
	Hand gun with hose
	Diaphragm pump for high pressure spraying
Two-wheel	Adjustable boom bracket
Dual Purpose	Includes:
Sprayers	Tank(s)
	Manifold
	Pressure gauge
	Relief valve
	Strainer
	Tank cutoff valve
	Optional:
	Hand spray gun
	Pasture broadcast nozzle kit
	Row crop boom
	PTO pump kits
	Diaphragm pump

Company: Sprayer Systems, Co.

Products	Features
844 & 855	Spray controllers
TeeJet 844	Basic control system
	Pressure or Flow control
	Three or five boom control
	Displays travel/application information
	Control nozzle capacity
TeeJet 855	Advanced control system
	Monitors flow from tanks and at nozzles
	Applies at four preset rates
	Manual or auto control modes
	Five boom control with united or individual control
	Sensor monitor display
	Two LED displays show travel info and application info
	Includes:
	Control console
	Nonvolatile memory
	Magnetic speed sensor
	Flow meter
	Pressure regulating valve & pressure transducer
	Installation & programming video & manual
	Connection cables
	Optional:
	Printer
	Pressure regulator bypass or throttling modes
734 & 744A	Sprayer Control
	Manual control only
	Up to three booms controlled
	Pressure control
	Controls solenoid or ball valves
	Consoles have:
	Master switch
	Increase/decrease switch
	Boom on/off switches
	Pressure gauge
	Include:
	Pressure regulating valve
	Cables and mounting hardware
734	For pressures to 100 psi
	Three 144A DirectoValve electric valves
744A	Pressures to 100 or 300 psi
	Optional 1, 3 or 5 boom control
	Up to five 144A or 344 EC-2 DirectoValve electric valves

Company: Tyler

Product	Features
AIM System	Positional control/GPS system
	Used on Flex Air or Patriot applicators
	Includes:
	Hawk Eye GPS guidance system
	AIM system software
	Two inch GPS accuracy
	Compatible with variable rate technology systems
	Possible to transport control unit between systems
Fluid Air M250	Granular applicator
	Broadcasts dry or impregnated fertilizer, herbicide or seeds
	DICKEY-john CCS100 controller used
	Synchronized conveyor meters to
	Venturi tubes
	Ground speed radar
	Optional:
	Granular Coapplicator
	WET-KIT for liquid applications
	Uses SMART soil organic matter testing equipment
SMART	Soil probe, organic matter sensing
	Soil sampling
	Radiance based system
Flex Air	Pneumatic Applicator
	Can meter up to four products
	Variable rate application
	Synchronized conveyors meter product to
	Venturi tubes
	Includes:
	Field Leveler Booms
	Display head
	Control module
	Optional:
	Coapplication
	WET-KIT
	AIM control system with Hawk Eye guidance

Company: Westheffer Co., Inc.

Product	Features
Commander	Truck mounted
	Controlled with Raven 440
	In-cab wing folding, leveling and height adjustment
	Includes:
	Foam Marker
	Flowmax hydraulic centrifugal pump
	Two boom sprayer
	Three section directo valves
	Nozzle assemblies & end row nozzles

Company: Westlake Equipment Company

Product	Features
Suvivors I&II	Both have the following:
	Telescopic swing nurse tank hitch
	Flat and coil shanks
	Can use DICKEY-john or Hiniker controllers
	Both have optional:
	Dual flow meter with hydraulic shut off
	Dual blade disk sealer & pressure springs
	Coulters with straight or offset shanks
Survivor I	Pull type tool bar
	Includes:
	Manual gauge wheels
	Hydraulic lift wheels & hyd. wing lift & fold
	Hi-Flo NH3 coupler
	B9500 meter matic & dual distributor manifolds
	Options:
	Walking tandems & tandem wheel gauge
	Outer wing hydraulic fold
	Wiese knives and sealers
Survivor II	Three point tool bar
	Includes:
	Choice between Flo-Trol or Meter Matics
	Pioneer NH3 coupler assembly & bleeder valve
	Hydraulic wing lift cylinders
	Optional:
	Flo-Trol or Meter Matic (whichever not chosen as std.)

Table 2. Information on Variable Rate Application Equipment Companies

The following companies contributed information, slides or diagrams with specific relevance to variable rate application equipment for use in this report. This is not a complete list of companies contacted.

Company Name	Phone	Fax
Ag-Chem Equipment Co.	612-933-9006	612-933-7432
5720 Smetna Dr.	Minnetonka, Mn	55343
Automatic Equipment Mfg. Co.	402-385-3051	402-385-3360
PO Box P	Pender, NE	68047
BEE Ag-Electronics	403-437-6988	403-437-6249
4320 97th Street	Edmonton, Alberta	T6E-5R9
Capstan Ag Systems	818-791-5911	818-791-5912
1777 La Cresta Dr.	Pasedena, Ca.	91103
Chandler Equipment Co.	800-243-3319	404-535-1265
PO Box 2533	Gainsville, Ga.	30503
Concord	701-280-1260	
3000 7th Ave N	Fargo, ND	58102
Del Norte Technology	817-267-3514	
1100 Pamela Dr.	Euless, Tx.	76040
Dickey-John Corp	217-438-3371	217-438-6012
PO Box 10	Auburn, Il	62615
Gallenburg Equipment, Inc.	800-533-2662	715-627-4557
w9112 Cherry Rd.	Antigo, Wi.	54409
Gandy Co.	800-443-2476	507-451-2857
PO Box 528	Owatonna, Mn	55060
Hagie Manufacturing Co.	800-247-4885	515-532-3553
PO Box 273	Clarion, Ia.	50525-0273
Hiniker Company	607-625-8621	
	Mankato, Mn.	66001
Illini FS	217-384-8300	217-384-6317
1509 E. University	Urbana, Il.	61801
Kinze Manufacturing	319-668-1300	
	Williamsburg, Ia.	
Linco Equipment Inc.	309-527-6455	309-527-6600
PO Box 37	El Paso, Il.	61738-0037
LOR-Al Products, Inc.	612-843-4161	612-843-3954
2200 Hall Ave	Benson, Mn.	56215
Micro-Trak Systems Inc.	507-257-3600	507-257-3001
PO Box 3699	Makato, Mn.	56002
Midwest Technologies, Inc.	217-753-8427	217-753-8426
2733 East Ash Rd.	Sprinfield, Il.	62703
Progressive Farm Products	800-788-1564	
	Illinois	
Raven Industries	605-335-143	605-331-426
PO Box 5107	Sioux Falls, SD.	57117
Rawson Control Systems, Inc.	319-283-2225	319-283-1360
116 2nd St. SE	Olewein, Ia.	50662
Remcor Inc.	903-532-6214	903-532-5216
PO Box 717	Howe, TX	75459
Rockwell Agricultural Systems	800-321-2223	
350 Collins Rd. NE.	Cedar Rapids, Ia.	52498-0120
Satloc	602-831-5100	
Spraying Systems, Co.	708-665-5000	708-665-5292
PO Box 7900	Wheaton, Il.	60189-7900
Stahly	800-678-2459	309-662-5409

PO Box 102	Bloomington, Il.	61702
Tyler	800-328-9128	612-843-2467
PO Box 249	Benson, Mn.	56215
Westheffer Co. Inc	800-362-3110	913-843-4486
PO Box 363	Lawrence, Ks.	66044
Westlake Equipment Co.	217-629-9675	217-629-8782
Box 91A	Riverton, Il	62561