PRECISION WEED MANAGEMENT RESEARCH ADVANCEMENT IN THE NEAR EAST

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ABSTRACT

Precision weed control research received considerable attention since the introduction of global positioning systems (GPS). GPS and geographic information systems (GIS) technologies may assist with field monitoring, particularly; in deciding what weed species to monitor? What weed densities are bypassing critical thresholds? and where? While advancements in precision agricultural research could be detected through the intensive publications in the developed world, these new technologies are less applied in underdeveloped countries. Instrumentation, among other aspects, is considered a limitation in introducing or developing precision agriculture techniques. This paper will highlight the recent advancement in research efforts in several Near East Countries in respect to precision weed management. Weed management techniques in these countries are less herbicide-dependent, which in principal might reduce the rationale behind adopting precision weed management technologies. Precision weed management relies on a wealth in weed biology information, as well as, on knowledge on weed population dynamics. Both of these scientific aspects received minor attention in underdeveloped countries. Nevertheless, the paper will provide a base line assessment of research efforts in this vital new approach. In addition, the review will outline possible advances and determine short comings in precision weed management techniques.

Keywords: Precision weed management, Near East, Jordan, advancements.

INTRODUCTION

Precision agriculture that combine high-accuracy positioning technologies, sophisticated software, machine guidance and metering systems, with crop analysis systems, and weather monitoring is changing the face of agriculture around the world. Precision farming allows farmers at all levels to achieve significant improvements in farming efficiency by applying the right inputs at the right place at the right time (Shaner, 2004). Benefits include increased yields, savings in time, higher productivity, reduced pollution, lower water use and precise applications of nutrients, seeds, pesticides, and water. Global positioning systems technologies provided farmers with unprecedented control over a wide range of farming machines and implements, with little or no user intervention.

Precision agriculture revolves around three key elements; a) saving time, by delivering significant timesaving opportunities; b) reducing costs, by using less inputs, by accomplishing tasks accurately, instantly and constantly, by achieving better water management, higher productivity; and by providing more efficient fuel usage, and c) environmental stewardship through reducing environmental impacts of farming. These three elements are the building blocks for the rise in the precision agriculture market.

Weed management

Weeds have been present since the beginnings of civilization and are not likely to disappear in the near future. It is well known that weeds pose a recurrent and ubiquitous threat to agricultural productivity (Buhler et al., 2000). The overall goal of weed management is to design the most appropriate method in a variety of situations that ensure a sustainable ecosystem and a minimum influence of nuisance weeds (Monaco et al., 2002). Weed management goes beyond control of existing weed problems and places greater emphasis on preventing weed reproduction, reducing weed emergence after crop planting, and minimizing weed competition with the crop (Buhler, 1996; Zimdahl, 1991).

Weed management approaches are frequently divided within the four categories of mechanical-, cultural-, biological- and chemical-methods. While the development and adoption of herbicides in the mid 20th century contributed to a decreased reliance on mechanical weeders on farms, these implements have continued to evolve and are very efficient and versatile in controlling weeds in a variety of cropping systems. Mechanical weed control can be achieved through several operations. Primary tillage contributes to weed control of those species that are propagated by seeds, by burying a portion of seeds at depths from which these seeds are unable to emerge. Primary tillage can also play a role in controlling perennial weeds by burying some of their propagules deep, thereby preventing or slowing down their emergence. Other propagules will be brought up to the soil surface, where they will be exposed directly to cold or warm temperatures or desiccation conditions (Coultier et al., 2007).

Secondary tillage are those operations that further pulverize the soil, mix various materials, such as fertilizer, lime, manure, and pesticides in to the soil, level and firm the soil, close air pockets, and control weeds (ASAE, 2004). Cultivating tillage equipments are also important mechanical weed management operations. These operations are used after crop planting to carry out shallow tillage to loosen the soil and to control weeds (ASAE, 2004). These implements are commonly called cultivators (Buhler et al., 1995; Steinmon, 2002). Cultivation tillage cause partial or complete burial of weeds causing mortality. In addition, cultivation cause uprooting and breakage of the weed root contact with the soil (Kurskjens and Kropff, 2001). Mechanical tearing, breaking or cutting the plant can also result in mortality of weeds (Cloutier et al., 2007). Cultivators can be classified in relation to contact area into; a) Broadcast cultivators, which are passed to cultivate with the same intensity at both on and between the crop rows; b) inter-row cultivators, which are only used between rows in row crops with a minimal risk to the crop and weed control; and c) intra-row cultivators, which are used to remove weeds from the crop rows.

Other mechanical weed control techniques include cutting and mowing. These operations are commonly used in turf, in rights of way, in vineyards, in orchards, in pastures and in forage crops. Cutting and mowing are used to promote crop establishment, to control weed size and seed production, and to minimize competition with the crop (Donald, 2006). Water-jet cutting using water at very high pressure (2000-3000 bars) using 5-25l/ min could also be an efficient way to cut weeds (Cloutier et al., 2007). Thermal injury created by subjecting weeds to fire, flaming, hot water, steam, and freezing are among the other methods that are used to mechanically control weeds. Such methods are attractive as rapid weed control is achieved without leaving hazardous residues in soil or water, but rather leave an erosion preventive dead plant biomass on the soil surface (Ascard, 1995).

Chemical applications, better known as herbicide applications, reside at the top of weed control methods. Herbicides are important tools for weed control and have improved production efficiency and facilitated reduced tillage production systems. Because of their effectiveness, herbicides and tillage are the dominant practices in many production systems. While the efficacy of herbicides is evident, they may also lead to environmental contamination, human health problems, and soil erosion. In addition, weeds persist by adapting to production practices and herbicide resistance continues to develop and spread (Buhler et al., 2000;Weis et al., 2008). Nevertheless, herbicides are expected to continue to remain in the toolbox of crop production (Duke, 1992). This technology provides selectivity, ease of use, efficacy, less labor requirements, and less costs, compared to any other alternative. There are many approaches to reducing costly herbicide use, such as banding combined with between-row cultivation, reduced rates, and spot application (Zimdahl, 1993). One of the major benefits is a reduction in cost due to reduced use of herbicides. It has been estimated that farmers can save $3 to $20/ha, depending on the herbicide, weed density and type of variable rate application (Shaner, 2004).

Precision weed management

Precision agriculture technologies can be utilized within the above described weed management categories to achieve the key elements of a) saving time, b) reducing cost, and c) environmental stewardship. Precision agriculture technologies can provide many advantageous for weed management practices. Weeds occur in patches and one of the promises of precision farming is a reduction in herbicide application by applying variable rates and treating only the weed patches instead of applying a uniform rate over the field (Shaner, 2004). In particular, mechanical weed management and herbicide application, combined with more accurate scouting and monitoring practices, can benefit much from the advancement in precision agriculture technologies. New technologies that include weed mapping using global positioning systems could and should be integrated with other effective weed management strategies. By bringing together information about weed spatial distribution and competitiveness, sprayer application technologies, and economics, we can begin to develop a precision weed management approach that minimizes our agricultural footprint. However, before these multiple benefits of precision weed management can be realized, there are barriers that will need to be overcome. These barriers include the cost of mapping weed patches, and increased risk. A number of challenges arise; one, get good information about the spatial distribution of weed populations and two, ensure that adequate weed control is obtained (Dille, 2009). Much work and research needs to be done in order to make precision weed management more user-friendly, less expensive and more robust before it will be widely practiced (Shaner, 2004).

Managing weeds on a subfield level requires measuring the varying density of weeds within a field (Weis et al., 2008). GIS analysis considering size and spatial distribution of infestations of invasive species on a land base can assist with developing appropriate control strategies for that species. Mapping weed infestations in an annual crop has implications not only for site-specific herbicide applications but also for planning future management strategies and understanding weed ecology (Smith and Blackshaw, 2009). Analyses of spatial distribution and size of infestations can assist land managers with selecting the appropriate strategy for controlling invasive species (Yager and Smith, 2009).

Remote sensing and associated spatial technologies provide tremendous opportunity to enhance weed management and improve–protect the environment through judicious use of the most efficacious control methods for a given site. Henry et al. (2004), examined the utility of hyperspectral remote sensing data for discriminating weeds from crops after herbicide application. Discriminant models successfully discriminated soybean from weeds 88%, on average, regardless of herbicide, rate, or species. Other results suggested that mapping grass weed patches in wheat is feasible with high-resolution satellite imagery or aerial photography acquired 2 to 3 wk before crop senescence (López-Granados et al., 2006). Remote sensing can also be invaluable asset for detection of invasions, assessment of infestation levels, monitoring rate of spread, and determining the efficacy of mitigation efforts for weed management. In combination with other technologies, GPS and GIS, sampling strategies can be devised to efficiently determine the location of weed populations in agricultural and wild land situations (Shaw 2005). Once we have an accurate weed species and density map, the “economically optimal rate” to apply in each grid cell was determined using algorithms programmed into a spreadsheet (Dille, 2009). Improvements in spatial and spectral resolution, temporal frequency, image turnaround time, and cost of image acquisition, combined with the realization of the value of the data, are enhancing the acceptance and usage of remote sensing technologies (Shaw 2005).

Herbicide applications can benefit from increased accuracy in application equipments. Precision application of postemergence herbicides is possible with a map of weed populations across the field. The challenge is to obtain an accurate map (weed species and density) at an appropriate resolution (grid cell = boom section or individual nozzles) (Dille, 2009). Potential benefits to the land managers and the ecosystem as a whole will come from reductions in inputs, reduced environmental liability from the detrimental effects of applying control measures to entire areas, crop yield increases through better management decisions, and early detection and effective management of invading species (Shaw 2005).

Other researchers have suggested using remote or on-the-go-sensing as information sources for making weed maps. Obtaining an accurate weed species and density map is a critical limiting component of implementing precision weed management; however it is clearly an approach that focuses our efforts on where the weeds occur and protects the areas where weeds do not occur (Dille, 2009). A hyperspectral imaging system coupled to a micro-spray heated oil application system was developed for weed control within the seed-lines of early growth tomatoes (Zhang et al., 2009). Real-time, sensor-driven site-specific herbicide management promises to overcome many of the scouting and map-making costs so long as weed species recognition accuracy continues to improve and commercial capital costs to decline (Swinton, 2005). The hyperspectral imaging system correctly identified 95%, 94% and 99% of tomatoes, black night shade and pigweed, respectively (Zhang et al., 2009)

The concept of site-specific weed management (SSWM) is to identify, analyze and manage site specific spatial and/or temporal variability of weed populations in order to optimize economic returns, sustainability of cropping systems, and environmental protection (Shaw, 2005). In recent years, technological development such as remote sensing, GIS and GPS have markedly increased the potential for SSWM. Site-specific weed control techniques have gained interest in the precision farming community over the last years (Weis et al., 2008). This method was prescribed frequently for improving herbicide use in fields. However, precise knowledge of when and where weeds occur in a field will also facilitate increased efficiencies of cultural techniques. Crop seed rate could be increased or planting pattern altered in dense weed patches to reduce weed competition. Timing or application method of fertilizers could possibly be manipulated according to weed spatial data to reduce weed establishment and weed competitive ability with the crop (Blackshaw et al., 2007). Nascent research on the profitability of site-specific weed management has focused on reduced herbicide use, ignoring significant information costs for scouting, making treatment maps, and patch herbicide application. Including these information costs results in few, if any, studies, fully covering added costs with herbicide savings (Swinton, 2005).

Intelligent weeders are currently under development and new technologies associated with precision agriculture are emerging in, cultivators, cutting, and mowing equipments. Åstrand (2002) presents an autonomous agricultural mobile robot for mechanical weed control in outdoor environments. The robot employs two vision systems: one gray-level vision system that is able to recognize the row structure formed by the crops and to guide the robot along the rows and a second, color-based vision system that is able to identify a single crop among weed plants. This vision system controls a weeding-tool that removes the weed within the row of crops. A first trial in a greenhouse showed that the robot is able to manage weed control within a row of crops (Åstrand . 2002).

The Sarl Radis weeders from France, has a simple crop detection system based on light interception and moves a hoe in and out of the crop row around the crop plants It is very effective in transplanted crops, but only when weeds are smaller than crop plants (Cloutier et al., 2007). Dedousis et al. (2007) described the design and performance of a novel mechanical system for inter- and intra-row weed control. The mechanical system consists of a rotating disc which acts in a horizontal plane and has a cut-out sector and a bevel cut at its circumference. The disc centre moves at a distance parallel to the crop row so that its swept area passes between the plants and also between the rows. Preliminary field results have shown this to be a very effective mechanism where approximately 60% of the weeds within an 80 mm radius of the crop are destroyed; at greater radii this increases to 80% of the weed population. Donald et al. (2001) developed a specialized mower to cut weeds between soybean and maize rows. Laser cutting has also been described as a potential energy-efficient alternative to weed control that delays the growth of weeds, decreases their competitive ability and eventually kills them. The laser concentrates large amounts of energy in a thin beam and can be directed precisely and quickly. Furthermore the laser beam can be focused in a narrow area to increase the energy in focus and decrease danger outside of focus. The approach could be as a precision guided tool used to cut weeds seedlings close to the crop plant at the very early growth stages. Another application could be as a mower tool to control weed on roadside or pavement, decreasing the need for precision guidance, hence probably increasing energy consumption. More research in areas that investigate total energy costs is called for. (Heisel and Christensen. 2000)

Biological weed control, which represents an economically attractive and ecologically sound management technique, can utilize such technologies. Weeder animals, such as geese, goats, sheep, and cattle, can be well monitored to categorize the need to direct the weeding activities of the animals, and also can provide early detection on possible weed shifts resulting from selective grazing by theses animals. Efficacy of Bioherbicide uses can be enhanced by precise monitoring of the advancements or retreats of targeted species.

Precision weed management in the Near East:

The current literature search did not yield many research results in precision weed management within Near East countries. A pioneer introduction of the concepts and applications of precision agriculture was in eastern Sudan. Golder

Associates Africa has been working with ASBNACO, a Sudan-based company that manages the Agadi farm, and the Arab Authority for Agricultural Investment and Development (AAAID), which has provided finance for testing the autosteer unit as well as technical support. Golder has introduced the first auto-steer tractor on the continent, to Agadi farm, an 80,000 ha rain-fed farm in Blue Nile state in eastern Sudan. The tractor is fitted with a GPS satellite guidance system that takes control of tractor steering and can maintain a preset course accurate to within 10 cm. The auto-steer unit has already helped reduce the average planting time on the Agadi farm by 60% compared with the previous two seasons (Howcroft, 2006).

The Agadi project is coordinated by the Precision Farming Unit (PFU), whose aim is to introduce site-specific farming, using GPS and GIS-based technology, for the commercial mechanized farming sector in Sudan. The PFU has set up a GPS farm survey section that produces accurate base maps for use in GIS systems. It has also undertaken spatial yield monitoring using GPS field monitors installed in combine harvesters. These monitors record yield variations within each field and produce yield maps for each section of land harvested. Moreover, the unit has successfully introduced 'controlled traffic farming' (CTF) using GPS-based self-steering tractors. CTF restricts the movements of tractors to deliberately chosen 'lanes' within the field so that operations occur sequentially in the same wheel tracks, thus reducing soil compaction and erosion and improving efficiency by eliminating overlaps when sowing seed and applying chemical sprays. The unit is currently developing a GIS-based farming information and management system. Future plans include the use of Infrared photography to identify weed infestations, and areas suffering from water stress or crop pest outbreaks. In the latter case, chemical applications can be specifically targeted, thus reducing the wastage incurred with conventional blanket spraying (Howcroft, 2006).

The International Center for Agricultural Research in the Dry Areas (ICARDA) utilizes many precision agriculture concepts. Such technologies, particularly, remote sensing, is incorporated within the research and development activities, particularly, in land use research, water harvesting and management, and range land studies. However, there is no specialized division that deals with precision agriculture technologies per se. Currently, precision weed management activates are not conducted at ICARDA (ICARDA, 2008)..

Private enterprises in the Near East countries are not utilizing technologies associated with precision agriculture. In my opinion, many factors can be associated to this ignorance of this rising technology. The small size of ownership is the first hinderer in that regard. For example, Jordanian agricultural enterprises under irrigation seldom exceed areas above 100 ha, with the average being 4 to 12 ha for each farm. These are mostly family-operated or owned. Within these farms, mechanized operations are not sued often. Many operations are handled by trained and non –trained laborers, making the need for advanced mechanizations (i.e., precise operations) less urgent. This small ownership predominates in many countries of the region.

Literature also describes several sophisticated instruments associated with precision agriculture techniques. The majority of the countries in the Near East are lagging behind in developing, as well as, in using such advanced technologies. A big obstacle for utilizing these techniques will be feasibility, maintenance availability, and the presence of technical support. These requirements are not likely to be available soon for producers. Theoretically, equipment can be imported from manufacturers, however, to gain on-farm training and master the use of such equipment, will need continuous customer support.

The key advantages of precision agriculture will be to save time, to reduce costs, and to provide environmental stewardship through reducing environmental impacts of farming. None of these factors is a crucial element at this time in most of the developing countries of the Near East. In fact, the sophisticated equipment associated will create extra expenses on the farmers. The lack of high prices of produced commodities prevents farmers from over using inputs. In reality, many nutrient deficiencies are observed among farms, while pest infestations, including weed infestations are very common. This lower use of pesticides and synthetic nutrients makes the impacts of farming on environments less prominent.

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