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UniSA's Agricultural Machinery Research Design Centre—Collaborative University/ Industry Research and Research Education in Agricultural Engineering*

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The Agricultural Machinery Research and Design Centre (AMRDC) at the University of South Australia has evolved over the past 25 years from a single mechanical engineering consultancy to a major national agricultural engineering research and postgraduate education centre. The paper traces the history of the development of AMRDC and focuses on the path of expansion of activities from cultivation machine design, tillage tool research, seed placement and plant growth interactions, to the move into horticulture and food processing machinery. Today's equipment includes the Tillage Test Track (a 250m continuous soil bin), the Seed Placement Test Rig (an indoor soil bin with interchangeable soils and a growth chamber) and Trial Plot Seeder. A post harvest processing facility is also briefly described.

Keywords: agricultural machinery research; agricultural engineering; horticulture; food processing

BIRTH OF A NEW RESEARCH FACILITY

THE LARGEST UNIVERSITY in South Australia is the University of South Australia (UniSA). In 2003 it had 31,861 enrolled students of which 1,098 persons enrolled as higher degree research candidates. UniSA had 2,133 staff of which 189 were classed as research only academics and another 730 were classed as teaching and research academics. UniSA has an institutional commitment to partnerships with industry, other educational providers and the community, in educational delivery and in research. It maintains a long tradition of working with industry to educate professionals. Since 1990, UniSA has had a Research Management Plan which has three major directions to inform research planning:

- Concentration of resources in selected areas of excellence.
- Development of a broader research culture to permit new areas of excellence to emerge.
- Measured growth of research student numbers linked to supervisory capacity in Research Institutes, Centres and Groups.

A key element of the strategy has been the selection and concentration of research firstly into Research Groups which are recognized as emerging areas of research strength, Research Centres which have a strong research track record and are recognized nationally and internationally for their research and Research Institutes which are much larger again and have a large critical mass of high-performing researchers, a common goal, clear leadership and well-integrated research plans. In 2003 UniSA had 30 recognized Research Groups, 18 Research Centres and two Research Institutes.

The Agricultural Machinery Research and Design Centre is one of the 18 and is currently working with three other Research Centres merged to form a Research Institute around the theme of sustainable systems and technologies. Research Centres within UniSA are provided with infrastructure funds based on research performance in the areas of grants, publications and research degree completions. They are required to have an industry-based advisory board and prepare an annual business plan.

DEVELOPMENT OF AMRDC

The foundations for the AMRDC were laid during the mid 1970s when a series of South Australian agricultural machinery manufacturers approached mechanical engineering staff at the then South Australian Institute of Technology to assist with the design of tillage and deep ripping machinery. The issue for the industry engineers at the time was one of gaining data on the forces acting on tillage and ripping machinery which was starting to move from smaller width equipment

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operated at low speeds to much wider equipment operated at higher speeds to utilize the increasing amount of power available from tractors.

This industry-driven desire for design knowledge encouraged testing to be undertaken to measure the forces on tillage equipment under local conditions. From these early industry collaborations grew a research interest and the undertaking of a Master's degree [1]. The work of [1] demonstrated the use of comparison testing of a range of tillage tools, gave performance data for chisel plough sweeps under a range of conditions and proposed an improved stump jump mechanism for wide sweeps [2]. The early work was well received by industry and the potential for further development was recognized and supported by some small research grants. This research was subsequently continued with final year mechanical engineering students who designed further test equipment and compared the performance of a range of tillage tools [3].

In 1983, a research grant was received from the National Energy Research Development and Demonstration Council which allowed the employment of the author as a graduate engineer on a full-time basis for two years. The work was to develop the Tillage Test Track and undertake research to understand and refine the design of sweep tillage tools for Australian conditions. The work led to a Master's thesis [4] and a Ph.D. thesis [5].

The work and facilities of AMRDC were seen by the Australian steel producing company BHP to be able to assist in their desire to develop a new grade of steel for the production of tillage tools. From 1986–89 AMRDC undertook testing using both the Tillage Test Track and field tests to compare the wear resistance of a range of alternative steel grades in a range of soils. The work led to research into the wear of tillage tools in collaboration with the CSIRO Division of Soils [6] and a Master's thesis [7]. Numerous final year projects were also conducted to investigate aspects of wear of tillage tools. With the advent of improved coatings for tillage tools, AMRDC employed a Materials Engineer to undertake wear testing and metallurgical analysis of many styles of hardfacing and surface treatments.

Hence, the growth of AMRDC was made by moving from an initial consultancy to undertaking research using final year mechanical engineering students, employment of mechanical, electronics, agricultural and materials engineers to undertake research and to involve them with research supervision. AMRDC has grown an international reputation with mechanical engineering schools and has hosted work experience students from France, Germany and The Netherlands who undertake six month periods of work experience based around the design of agricultural machinery. With the growing reputation of AMRDC, it has attracted research students from Iran, Papua New Guinea, Thailand for Master's by research and Ph.Ds. Their topics have covered issues specific to their home country, specific to Australian agriculture plus issues of a more general nature. International links with Israel, from which several agricultural engineers have spent their sabbatical with AMRDC, and the employment of agricultural engineering doctoral graduates from Silsoe Campus of Cranfield University have helped strengthen AMRDC's research supervision and research development. These links have resulted in reciprocal visits of AMRDC staff and research students.

DIVERSIFICATION OF ACTIVITIES

Whilst AMRDC continued its work in tillage machinery, because it was working with agricultural machinery manufacturers its reputation in Australian agriculture grew and it started to work with the dried apricot industry to help mechanize on-farm activities and then the dried grape industry to help improve its processing machinery. The processing work in the dried grape industry led to an interest in the development of new processing technologies for the grain legume splitting industry and a Ph.D. [8]. Research work likewise expanded into mechanization for aquaculture, leather tanning and confectionary manufacture.

UNIQUE FACILITIES

UniSA has developed some unique facilities. The Tillage Test Track is a continuous soil bin. It has two semi-circular curves of 50m diameter joined by two straights of 50m length, giving 250m of travel per lap. The Tillage Test Track is filled with 500 tonnes of a sandy loam soil in a section 2.5m wide and 0.3 m deep. Constructed in 1984 it has now been used for 14,000 laps of testing. A photograph of the Tillage Test Track is shown in Fig. 1. It is basically a tractor which self-steers via rails; it has a widened rear axle and tows two trolleys each capable of tilling the soil up to 2 m in width, levelling the soil with a grader blade and compacting the soil with a roller. The whole combination can operate at speeds up to 15 km/h. Testing may be conducted in either trolley, with instrumentation located in the rear cabin. Soil moisture content is controlled via water addition from a water cart. The Tillage Test Track has been used for tillage tool force measurement, ground engaging tool wear evaluations, quantification of ground following abilities, trash flow experiments, soil throw and furrow profile analysis.

To complement the Tillage Test Track, AMRDC has developed a Seed Placement Test Rig. This equipment is an indoor soil bin facility into which soil is prepared in moveable bins in a section 1.5m wide, 2.9m long and 0.1–0.25m deep. For seed placement tests the bin is moved into the test position and a test frame is pulled at speeds up

Fig. 1. UniSA Tillage Test Track

to 15km/h over the bin with the tillage tools engaging the soil at the desired depth. The test frame is fitted with seed metering equipment which is capable of placing both seed and fertilizer in the soil. Once machinery has passed through the soil, the soil profile can be measured, a post seeding treatment may be subsequently undertaken, such as presswheels or harrows, and another soil profile taken. After testing, the bin can be taken to a growth chamber where light and temperature can be controlled. Both emergence data and subsequent seed placement data can be gained. Seed placement is gained by excavation and digitization of the seed position in the soil profile. The equipment has been used by research students and industry to quantify tillage tool seeding boots and post seeding treatments on seed placement and emergence. See Fig. 2 below.

In addition to the controlled laboratory tests, AMRDC has developed a range of field test equipment. A trailed Trial Plot Seeder has been built in three variations. Each is a trailer-based frame which fits within the road transport width of 2.5m; it has an open frame for mounting tool bars of around 1.8m width. The Trial Plot Seeder can be fitted with sections of machines to simulate a whole machine for field crop responses to machinery settings, or individual tools may be mounted in a three dimensional force measuring frame. During 2004 the AMRDC tractor was fitted with GPS guided steering.

For its tillage work, AMRDC has made exten-

Fig. 2. UniSA Seed Placement Test Rig

Fig. 3. UniSA Trial Plot Seeder

sive use of UniSA's Civil Engineering's soil laboratories and AMRDC has provided specialized triaxial soil testing equipment that is also used for civil engineering studies.

For its post harvest processing research AMRDC has developed a processing laboratory which focuses on separation of products via air, vibratory and washing methods. This equipment has been used to compare performance of machinery design variations and the development of new equipment. Of particular note, the processing facilities, supported by the Dried Fruits Research Council, were used over a 10 year period to guide the upgrading of Australia's dried grape processing lines. The work was undertaken by five UniSA staff, eight final year mechanical engineering students and three visiting researchers from Israel. The quality of the work introduced into the processing line and the involvement of students was recognized through the upgraded processing line of Mildura Co-operative Fruit Company winning the 1994–95 South Australian Engineering Excellence Award in Manufacturing Facilities. The work on improving the washing of dried grapes also led to a Master's thesis [9].

CURRENT PROJECTS

Here is an outline of what AMRDC is doing:

- has a broad mix of activities which are industry focused. Undertakes a programme of participatory farming systems research using machinery trials and experiments supported by local groups of farmers in zones around South Australia. The work is centred on the understanding of performance characteristics and defining the best operational settings for tillage and seeding equipment. The work is field trial-based and uses virtually all of the commercial seeding equipment currently available to South Australian farmers. The work was part of a project that received an award in the 2002 BHP Billiton National Landcare Research Awards.
- provides collaborative research and development services to local tillage and seeding equipment manufacturer Horwood Bagshaw. The work includes product design and testing of cultivators and airseeders from concept through to manufacture. This work was awarded the Australian Business and Higher Education (BHERT) 1999 Award for Outstanding Achievement in Collaborative R&D.
- is working on the development of an energy efficient vibratory ripper suited to soil loosening in vineyard rows. In addition to machine design the research is also developing strategies for control of soil compaction and soil ameliorant application through the soil profile.
- also undertakes contract product development of specialized soil testing laboratory mechanization equipment, design and testing of earthmoving machinery and attachments to certification standards, testing of spray equipment, expert witness and dispute resolution.

RESEARCH EDUCATION

During 2004 AMRDC hosted six overseas mechanical engineering work experience, each for six months and has three Ph.D. research candidates, one working on improved tractive performance for zero-turn radius vehicles, another working on energy efficient deep ripping using vibratory tillage and a third studying the threshing of dried grapes with the aim of maximizing

capstem detachment whilst minimizing berry damage.

Also, during 2004, UniSA formally introduced a statement of the qualities research degree candidates will develop during their candidature in order that the graduate:

1. has an understanding of current research-based knowledge in the field, its methodologies for creating new knowledge and is able to create, critique and appraise new and significant knowledge.
2. is prepared for lifelong learning in pursuit of ongoing personal development and excellence in research within and beyond a discipline or professional area.
3. is an effective problem solver, capable of applying logical, critical and creative thinking to a range of research problems.
4. can work both autonomously and collaboratively as a researcher within a particular discipline or professional area and within wider but related areas.
5. is committed to ethical action and social responsibility as a researcher in a discipline or professional area and as a leading citizen.
6. communicates effectively as a researcher in a discipline or professional area and as a leading member of the community.
7. demonstrates international perspectives in research in a discipline or professional area and as a leading citizen.

The aim during the research degree is for the candidate to progressively develop and recognize the above qualities throughout their candidature via an initial Statement of Agreement (progressively developed over their first six months, full time equivalent (FTE)), Research Proposal (completed within six months FTE of commencement), Reviews of Progress (completed every six months), annual seminar and a Final Review of Progress (must be completed before graduation). The Final Review of Progress provides a summary of each quality interpreted by the particular and unique research degree experience. Together the thesis and the Final Review of Progress provides a totality of the candidate's research experience for self-knowledge, as information for prospective employers and as an indication of the University's quality measures.

To support the one-on-one supervisor/research candidate relationship during which over a three year period for a Ph.D. (two years for a Master's) the student develops a thesis for examination; they are encouraged to attend the University-wide Research Education Support Activities (RESA). These activities are generally held in two-hour workshops and repeated several times per year to allow all research candidates to undertake the session at the time that they require. The following are the main topics covered:

1. Literature review

Outlines the nature and role of the literature review within academic research writing. The first exercise asks participants to work together on example texts to identify the function and structure of research literature reviews. Common misconceptions and pitfalls in the writing process, and the steps involved in writing and structuring the literature review are considered. This is followed by an exercise that aims to stimulate reflection upon the constructive and critical nature of the literature review in relation to each participant's research. The workshop concludes with helpful tips about processes for finding, reading and managing the research literature.

2. Academic writing

Provides an introduction to academic writing working from example texts to demonstrate the structural, referencing and argumentation techniques writers use to achieve clarity and persuasiveness. It forms the foundation for the Thesis writing workshops.

3. Research proposal

A key element of the commencing programme; the research proposal workshop pulls together previous workshops on the literature review and research methodology and design. In addition to provision of information about university research proposal guidelines and procedures, this workshop outlines the three interlocking elements that underpin good research proposals: explication of the problem, location within a research literature, clear outline of the methodological rationale and method. Candidates are stepped through each section of the proposal writing process and, in groups of four, invited to bring the key elements together in a peer presentation and feedback session.

4. Oral presentations

Designed to support the development of oral presentation skills and confidence for beginning researchers. It provides information about how to plan and present an oral presentation for a conference or other academic forum. Participants are asked to prepare and present a brief, semi-formal peer presentation, and to provide constructive and supportive feedback to fellow presenters. Depending on numbers and demand, presentations can be video-taped and screened as part of the feedback process in this or a following workshop.

5. Thesis writing I and II

Conducted over two sessions and covers thesis writing, styles and structures. Activities involve transforming descriptive thesis statements into critical arguments, writing hypotheses and questions, writing the discussion, introduction and methodology sections, writing tips for linking thesis sections together and abstract writing.

6. Time management, supervision and related matters

Explores 12 case studies designed to stimulate discussion about a range of issues that can arise in the research process. Topics include communicating effectively with supervisors, candidature and scholarships policy, time-management, writer's block, procrastination, authorship policy, casual employment, intellectual property and research maintenance allowance. The workshop aims to provide basic information about the rights and responsibilities of a research degree candidate at the University of South Australia, as well as useful strategies and tips in managing the relationships and resources that support the research process.

In addition to the above workshops the University of South Australia also holds a Writers' Circle for international research candidates. It aims to develop clarity in written academic language. Each series of five two-hour weekly sessions focuses on developing skills and strategies to apply when drafting and editing a proposal, research paper or thesis. During the sessions participants receive feedback on how their written language expresses meaning. This includes developing strategies related to choice of words, sentence structure, use of verbs, paragraph structure, developing a logical flow of ideas and expressing an argument. Through structured activities participants develop editing strategies and apply them to their own drafts (or 'work-in-progress') as well as drafts of other participants.

CONCLUSION

Australian Universities like most of the world have rationalized their teaching programmes on the basis of viability; AMRDC has found a niche in the application of mechanical engineering to agriculture. The connection of industry's thirst for pertinent information with University research infrastructure has provided a unique bond that has allowed academically rigorous research to permeate through to production of agricultural machines used by the Australian agricultural industry. The concentration of research equipment and infrastructure available within a university for use in collaboration with industry has allowed a sharing of resources and expertise to provide a cost effective solution to current problems and a training ground for engineers. Further information about the Agricultural Machinery Research and Design Centre at the University of South Australia is available via the Internet at www.unisa.edu.au/amrdc

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