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IHSG

President:

Dr. Phil Rolston
Ag Research Ltd, PO Box 60
Lincoln
New Zealand
Phone +64 3 3218604
Facsimile: +64 3 3218811
E-mail: phil.rolston@agresearch.co.nz

Newsletter Editors:

Dr. Jason Trethewey
AgResearch Ltd, Private Bag 4749
Christchurch 8140
New Zealand
Phone +64 3 3218603
Facsimile: +64 3 3218800
E-mail: Jason.trethewey@agresearch.co.nz

Nicole Anderson
Oregon State University Extension Service
2050 NE Lafayette Ave.
McMinnville, OR 97218
United States
Phone +001 503 5539922
Facsimile: +001 503 4723054
E-mail: Nicole.Anderson@oregonstate.edu

2013 workshop

Editor's note: The southern hemisphere is beginning the harvest season while the north is in the midst of winter weather conditions. In this issue, we focus on highlights from the 2013 IHSG Workshop that took place in September in the Canterbury region of New Zealand. On behalf of all of the workshop participants, I would like to extend a big thank you to the local organizing committee and others in New Zealand who were instrumental in putting together an excellent IHSG event. This is issue 49 of the newsletter. Details of the contact person in your area have been updated and are listed on the back page of the newsletter and on the IHSG website http://www.ihsg.org/. Please remember to send articles to the newsletter editors or to your area contact person to be included in future newsletters.

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President's Column

Welcome to the 49th Newsletter of the IHSG. At the very successful 5th IHSG Workshop at Methven, New Zealand in September 2013, Birte Boelt (Aarhus University, Denmark) handed over the Presidency after eight years in the role. Birte took over the role from William (Bill) Young (Oregon State University) at the Winchester, UK workshop in 2005. On behalf of the IHSG we extend a big vote of thanks to Birte for the work she has done in leading the group over the last eight years including our 7th Conference in 2010 at Dallas, Texas and our recent Workshop in New Zealand. Several previous presidents were at the Methven workshop; John Hampton (Lincoln University, NZ) and Bill Young.

Thomas Chastain of Oregon State University is your new President Elect. Tom brings a wealth of understanding on physiological processes in seed production. This newsletter contains a brief biography on Tom. The executive committee and regional contacts are listed on our website (www.ihsg.org). Barthold Feidenhans'l continues as treasurer; Jason Trethewey has been joined by Nicole Anderson as newsletter co-editors.

A big thanks to the Methven local organizing committee (Richard Chynoweth, Murray Kelly, Bede McCloy, Jason Trethewey, Hugh Wigley and Phil Rolston) for putting together an enjoyable workshop. The workshop was attended by 82 participants from 12 countries. During the four days of the workshop, mornings were spent with presentations and discussions and afternoons on farm visits to seven farms, four field research locations and a seed cleaning store. Day 2 of the workshop was a joint International Forum hosted by Foundation for Arable Research (FAR) and attended by 150 local seed growers. The feedback from participants was very positive. In giving a vote of thanks on the final day Andres Mondrop of DLF Denmark commented that he was impressed at the high level of cooperation and interaction demonstrated by growers and researchers and between the various research groups, FAR the farmer levy research and extension organization, the University and Institute researchers and the seed company agronomists. He noted the enthusiasm of the research teams and there vision for achieving even higher seed yields in the future. This newsletter has a summary of the paper and presentations.

The 5th IHSG Workshop, in an established tradition, followed the IGC (International Grasslands Congress) held the previous week in Sydney. There was a good seed research section at Sydney and a summary of these papers are in this newsletter. The IGC attracted a wider tropical seed research input.

The next IGC is in late 2015 in New Delhi, India. This timing will cause some of our member's problems as we will have our 8th IHSG Conference in 2015. The IHSG business meeting made several important decisions on future conferences; while it waits for the IGC to return to a four year cycle in 2019. We will have two conferences over the next four years; Lanzhou, Gansu Province, China in mid-2015 and Pergamino, Argentina in 2017. In our 33 year history we have met in developed countries with mature seed industries. The next two conferences will take us into countries with developing seed industries.

Phil Rolston

President

President Elect - Biographical Summary

Thomas G. Chastain, Oregon State University

Dr. Chastain conducts research on management, physiology, and ecology of seed crops. He teaches three courses at Oregon State University: Seed Production, Crop Ecology and Morphology, and Physiology of Crop Yield. His research program is focused on addressing problems that are of economic importance to producers of Pacific Northwest seed crops. While the research is often directed at solving a practical problem or developing new applications of previous research, the work also serves a secondary goal of increasing our understanding of the underlying biological processes limiting greater economic and environmental efficiency of seed crop production. He is a four-time winner of the Outstanding Teacher in the Department of Crop and Soil Science, and his teaching and student mentoring has been recognized by the George Hyslop Professorship Award.

Dr. Chastain earned a B.A. degree in Biological Sciences from California State University, Chico, and M.S. and Ph.D. degrees in Crop Science at Oregon State University. He served as Assistant Professor of Seed Physiology for two years at Washington State University before returning to the faculty at OSU in 1989.

John Hart Retires from Oregon State University and Herbage Seed Research

Nicole Anderson and Phil Rolston

After nearly 30 years as the Extension Soil Specialist at Oregon State University (OSU), John Hart has now fully retired. A native of western New York, John completed both a Bachelor's and Master's degree at the University of Arizona before earning a Ph.D. in Agronomy at the University of Nebraska in 1976. John worked at California State University at Chico for 9 years before arriving in Oregon and beginning what became an impressive career in crop nutrient management. While members of the International Herbage Seed Group (IHSG) are most familiar with his work in grass seed nutrient management, John also ran an active research and education program in wheat, peppermint, Christmas trees, carrot seed and cranberries, among others.

Throughout his tenure at OSU, John was undoubtedly a strong research leader who always provided assistance to anyone who asked. He actively cooperated not only with other University scientists, but with growers, consultants and the seed industry as a whole. In addition to conducting small plot research, he maintained an active program of on-farm trials that were carried out in cooperation with growers and others in the industry. When field burning was phased out in Oregon John worked alongside his colleagues to assist grass seed growers to overcome soil fertility issues and develop new fertilizer management practices. He was the first to show and quantify nutrient removal that occurs when straw is baled and demonstrated how effectively nutrients were recycled in a full straw load system. His work with soil nitrogen (N) helped define economical optimum N application rates for several species of grass seed crops. John often described himself as a "nutrient nerd", but those who worked with him in Oregon and overseas valued his understanding of soil nutrients.

Even though John's career has shifted to part-time in recent years, his pursuit of accomplishments has not dwindled. Over the last several years, he has made a concerted effort to finish long-term projects including publishing a series of nutrient management guides that summarize research information from the past 25 years. Russ Karow, John's long-time colleague and current head of OSU's Department of Crop and Soil Science, recently commented that "John has cultivated his grumpy old man persona over time but he has a heart of gold and the inquisitive mind and drive of a new faculty member. He strives to help his colleagues and the audiences they collectively serve in all that he does and has succeeded handily in this endeavour." John has been a strong mentor for young professionals who work in herbage seed production in Oregon and across the world. Rene Gislum, IHSG member from Denmark, says, " There is no doubt that John is very eager to get scientific results out to farmers, which is exemplified in two papers we wrote together for the IHSG meetings in Norway in 2007. These papers have been a great inspiration for me and I use his work on soil nitrogen in my projects today."

John has been a long-standing member of the IHSG and has contributed a great amount of knowledge to the understanding of soil fertility in herbage seed systems across the world. He made numerous trips to speak at professional meetings and visited with researchers and growers in New Zealand, Canada, Australia and Europe. "We have had the privilege to share knowledge and data with John, as global scientific collaboration should be," says Birte Boelt, past President of IHSG, and Gislum. The New Zealanders who collaborated with John greatly appreciate the insights he brought to their understanding.

We value the contributions that John made during his long career in herbage seed research. His work will have lasting impacts on our understanding of nutrient management. We wish him the very best in his retirement!

Highlights from the International Herbage Seed Group Workshop

Methven, South Island, New Zealand
22-26 September 2013



On the following pages of this newsletter edition, you will find several of the presentation abstracts provided at the recent IHSG workshop in New Zealand. Workshop participants not only had the opportunity to listen to some excellent talks but were also treated to many well-organized farm visits and were given opportunities to interact with local herbage seed growers. The workshop organizing committee did an outstanding job of demonstrating their research trials and providing the group with important insights into the regions diverse cropping systems. Overall, it was a great opportunity to learn new information and network with a great group of IHSG members from across the globe.

Thanks to all of those who attended and especially to our hosts in New Zealand!

Working within nitrogen limits

René Gislum, Simon Abel and Birte Boelt
Aarhus University, Denmark

Producing herbage grass seed within nitrogen (N) limits is a challenge for farmers. The present regulation system used to define the N application rates to agricultural crops in Denmark, is based on an N and seed yield response curve and using actual N and seed prices to calculate economical optimum N application rate (ECO-N) per hectare. Calculation of ECO-N is made for each agricultural crop and deduced by approximately 15% to get the advisable N application rate, which is the rate that farmers are advised to use and can buy without having to pay tax on.

The total amount of N at each farm is then the sum of hectares x the "advisable N rate" for each crop. It is up to the farmer to decide how he/she wants to divide the total amount of farm N between the individual crops. However, as advisable N rate is approximately 15% lower than ECO-N there is a high risk of failure of the crops if N is moved between the crops.

It has been an on-going process to develop a novel N regulation system with the purposes to reduce N leaching to the environment, but still maintain the possibility for farmers to harvest high seed yields. The solution is a new regulation system where Denmark is divided into high productivity areas (HPA) and environmental sensitive areas (ESA). It seems that there will be no limit for N application rate at HPA whereas N application rates at ESA will be further reduced compared with the

current advisable N rates.

Introducing a novel N regulation system in Denmark will require re-calculation of ECO-N using data from high productivity areas and optimum growing conditions. At the same time we will have to develop production systems based on an even lower N application rate than what we have used so far. The purpose of this abstract is to show production methods and results that can be used for HPA and ESA in Denmark.

Nitrogen rates for ryegrass seed crops in Canterbury, New Zealand

Authors: Phil Rolston[1], Bede McCloy[2], Richard Chynoweth3 and Jason Trethewey[1]
Institution: [1]AgResearch, Lincoln; [2]NZ Arable Ltd, Christchurch; [3]Foundation for Arable Research, New Zealand

Canterbury region is a major forage seed producer for domestic and export markets. Nitrogen (N) is one of the most expensive crop inputs and accounts for approximately 50% of the carbon footprint in a grass seed crop. Nitrate contamination of water from agriculture generally is a concern for Regional Government. In the past seven years we have undertaken 28 N rate and timing trials in commercial perennial and hybrid ryegrass seed crops, in which all inputs except N have been grower managed. Soil mineral N (ammonia and nitrate) in the top 30 cm was monitored and N uptake by the crop assessed

Seed yield in nil N treatments averaged 1480 kg/ha, compared with 2240 kg/ha at the optimum spring N, an increase of 760 kg/ha or 50% more seed. The average amount of applied spring N for the optimum seed yield was 138 ± 8 kg N/ha (± SEM). The average soil mineral N was 38 ± 4 kg N/ha, indicating the combined applied and soil N requirement for optimum seed yield is 176 kg N/ha (138 + 38 kg N). The suggested spring N rate for ryegrass seed crops is 176 minus the soil mineral N (0-30 cm).

Nitrogen rate responses are often linear before reaching a plateau, where extra N does not increase seed yield and decreases profitability. In some cases high N rates decreased seed yields due to early crop lodging. On average 1 kg applied N produces 6.0 kg seed.

Many of the trials used a simple 50:50 split application with the first application at closing (the date of last defoliation), with the second application three weeks later.
More recent research has shown there is a wide window for the second application, with little difference between three and nine weeks. Many growers also apply a late winter N at 30 kg N/ha when 10 cm soil temperatures reach >6°C to boost grass growth to feed lambs and sheep being grazed on ryegrass. This application is 6 to 8 weeks before closing. We have not included this winter application as part of the
spring N rate prediction.

When seed growers reduced their spring N rates they reported reduced lodging and higher seed yields. We now understand that there is a strong interacting effect between the effectiveness of the plant growth regulator Moddus® (trinexapac ethyl-TE), the date of the last spring defoliation and N rate and timing. Early lodging (days to 50% lodging) decreases seed yield 21 kg/ha/day. Delaying the date of second N application often delays the onset of lodging and enhances seed yield.

Managing lodging across N rates trials is essential to ensure the N response is not compromised by lodging. Predicting grass seed N requirements based on plant N concentration was first evaluated in the 1990's. This has been an elusive goal to implement but the use of on farm sensing technology is currently under investigation as an option for precision N application.

Ten years ago in grower surveys we found average spring N application rate was 230 kg N/ha. Many growers are now using approximately 150 kg N/ha; a reduction of 80 kg N/ha or 35% less N applied. Effective management practices can and has improved the economic and Environmental efficiency of seed production in Canterbury.

Nutrient recommendation and practices for perennial ryegrass seed production in Oregon

John Hart
Oregon State University, USA

Perennial ryegrass seed production is produced in western Oregon's Willamette and Tualatin Valleys as well as the Silverton Hills. Nutrient management differs somewhat within the primary production areas of the region, the mid and south Willamette Valley.

Soil pH is the primary concern in both the mid and southern Willamette Valley. To maintain adequate soil pH, lime is applied before planting or topdressed during the stand life. Nitrogen is applied by all growers and is the nutrient receiving most attention. Fall N application is standard with the rate varying by production area.

Spring N is applied at rates 10 to 15% above Oregon State University's recommendations of 135 to 180 kg/ha. The spring N is divided into two and sometimes three applications. Most of the N is supplied as dry urea. Some liquid urea-ammonium nitrate solution is used.

After nitrogen, potassium is the nutrient likely applied in both production areas. Application rates vary from 65 to 75 kg/ha in the mid-valley and 65 to 220 kg/ha in the southern portion of the Willamette Valley. Mid-valley K is applied as a standard practice where in the south valley, rates are based on a soil test.

Other nutrients applied are phosphorus, sulfur, magnesium, and boron. Annual S application is typical. Boron is rarely used. Phosphorous application without using a soil test is standard in the mid-valley where application is based on a soil test in the south valley. Magnesium in dolomitic lime is part of the programme to maintain soil pH. In the south valley it also is applied as K-Mag in the spring.

An introduction to plant growth regulators for use on grass seed crops

Thomas G. Chastain
Oregon State University, USA

Plant growth regulators (PGRs) are organic compounds, other than nutrients, that when applied affect plant processes such as growth and development. Since growth and development processes are mediated by hormones synthesized in the plant, those processes can be successfully manipulated by application of the appropriate PGR. PGRs are often active at low concentrations but have pronounced effects on the plant akin to hormones when applied at the correct timing. PGRs may affect growth, development or both processes.

PGRs may be naturally occurring compounds or synthetic analogs. PGRs are classified into several groups by their activity or function in the plant or by their mode of action: gibberellins (GA) and synthetic analogs, onium compounds, triazoles, acylcyclohexanediones, cytokinins and synthetic analogs, ethylene, ethylene biosynthesis inhibitors, and auxins and synthetic analogs. Some herbicides and fungicides may have PGR properties.

PGR use in grass seed crops is not a new phenomenon and the most widely researched and used of the early PGRs was paclobutrazol, a triazole that affects ent-kaurene in the GA biosynthesis pathway. GA is the hormone responsible for stem elongation in grasses and as a result, seed yield can be increased and lodging reduced by applications of this PGR. While this PGR worked well in some species such as the fine fescues, inconsistent results and occasional soil persistence problems eventually ended its use in other important grass seed crops.

Trinexapac-ethyl (TE) and prohexadione-calcium (PC) PGRs are acylcyclohexanedione inhibitors of the 3-ß hydroxylation of GA. These PGRs have been widely adopted for use as a lodging control agent in seed production of several cool-season grass crop species. While TE and PC shorten stems and reduce lodging, seed yield may be increased even when the incidence of lodging is low. The most common effects of acylcyclohexanedione PGR application are increased floret number, seed set, seed number, seed yield, and harvest index. PGRs increase the efficiency of carbon partitioning to harvested seed and tend to reduce the partitioning to stems and leaves. The efficacy of PGR applications is influenced by seasonal timing, environment, nitrogen management, residue management, and other management practices.

The next generation of PGRs will likely be even more effective and economical than those presently available in grass seed crops.

Current on-farm usage of plant growth regulators in Oregon

William C. Young III and Mark E. Mellbye
Oregon State University, USA

In the late 1990s, a new generation of plant growth regulators (PGRs) became available. These foliar-applied chemicals reduce growth through a reduction in plant level of gibberellins, and are applied to fields to reduce crop lodging, facilitate swathing, and to increase seed yields. Two PGRs are currently registered for use on grass seed crops in Oregon: Palisade® (trinexapac-ethyl) and Apogee® (prohexadione-calcium), both foliar applied products with similar modes of action in plant species.

Use of these PGRs has become an accepted crop production programme for many Oregon seed producers. OSU and private researchers have conducted many experimental trials with PGRs on perennial grass seed species and have shown consistent results from applications to perennial ryegrass, tall fescue and fine-leaf fescue species, with seed yield increases ranging from 15 to 40%. Seed yield response on annual ryegrass, however, has been less consistent with yield increases of 0 to 10%.

In 2009, usage estimates given by Syngenta Crop Protection, Inc. (Palisade®) and BASF Corporation (Apogee®) suggested that between 60 to 70% of grass seed acres were treated with PGRs. These estimates, based on their product sales, indicated that three-fourths of the fine-leaf fescue acreage was treated; two-thirds of the perennial ryegrass acreage was treated; one-half of the tall fescue acreage was treated; and one-third of the orchard grass acreage was treated at that time.

Recently (2013), a survey was taken by interviewing agronomists marketing PGR products to their clientele to ascertain specific usage in regards product preference, rate and tank mixed applications. These interviews showed a strong preference for the trinexapac-ethyl (Palisade®) product, largely driven by Syngenta Crop Protection's aggressive pricing position relative to BASF Corporation. Table 1 summarizes the information gleaned from our recent interviews.

In summary, over 90% of perennial ryegrass and tall fescue acres are now routinely treated with PGR. Application of PGR is now commonly made as a tank mix with a fungicide. Increasingly, variable rate applications are used to reduce growth regulator cost.

Table 1. PGR survey of current use on major grass seed crops in the Oregon's Willamette Valley, 2013*

Crop species	Estimate % Area treated	Palisade rate used in 2013		Timing
		Range (oz/ac)	Average (oz/ac)/ (g TE/ha)	
Annual ryegrass	12	8-20	16 (210 g)	Before 50% heading
Perennial ryegrass	93	8-32	24 (175 g)	2nd node on irrigated; later on dryland
Tall fescue	90	16-24	20 (140 g)	Late flag leaf to 10% head emergence
Fine fescue	90	16-24	22 (190 g)	Early heading
Orchard grass	50	16-24	20 (175 g)	Late boot stage

* Based on input from agricultural field representatives who work with seed farmers, 2013

How does Moddus® (Trinexapac ethyl) straw shortener influence seed yield in perennial ryegrass seed crops?

Richard Chynoweth
Foundation for Arable Research, New Zealand

Three diploid perennial ryegrass (Lolium perenne L.) cultivars, ‘Meridian’, ‘Bronsyn’ and ‘Grasslands Impact’ containing the AR1 endophyte were sown on 1 April and 14 May 2008. A subsequent application of Moddus (a.i. 250 g/l Trinexapac ethyl) plant growth regulator was used at three rates to examine the relationship between seed and stem dry weight in relation to thermal time.

Seed filling of ‘Meridian’, ‘Bronsyn’ and ‘Grasslands Impact’ followed a sigmoidal growth pattern (slow after flowering/anthesis, followed by a period of rapid growth and then a dry down phase where seed dry weight is constant). The time from peak anthesis until 95% of final seed weight was constant for all cultivars and Moddus treatments at 443°C days (base temperature 0 °C). Therefore the time from anthesis until crop maturity is determined through the temperatures experienced by the crop and is outside the control of growers.

The application of Moddus increased seed yield by approximately 26% for each 800 ml/ha applied from 1715 (0 ml/ha) to 2195 (800 ml/ha) and 2722 kg/ha (1600 ml/ha). The seed yield increase from Moddus was achieved by increasing the rate of seed filling per seed head, which increased the number of seeds/m^2.

For all cultivars, 1600 ml/ha of Moddus produced the highest seed yield and the shortest total stem length. There was a 0.15 m reduction in length between 0 and 1600 ml/ha of Moddus. Stem dry weight increased to a maximum at 350°C days following anthesis. Thus, stems competed with growing seeds from anthesis, throughout the lag phase until approximately 75% of final seed weight.

When seed demand for carbohydrate was low (lag phase and early seed growth), the stem was competing with the seed. As seeds grew and their demand for carbohydrate developed, they drew reserves from the stem. At harvest, stems were 25% heavier than at anthesis which suggests they were a net sink for carbohydrate post anthesis and that there was further carbohydrate available for seed production.

Shorter stems (1600 ml/ha Moddus) competed less with developing seed compared with longer stems, suggesting greater amounts of carbohydrate are available for seed production when stems are shorter.

The wish list of New Zealand seed producers

Bede McCloy
NZ Arable, New Zealand

New Zealand Seed Producers are part of the NZ arable sector which produces grains and seeds on approximately 2000 properties, comprising almost 200,000 ha. About 500, mainly from the Canterbury region, grow the majority of the crops - apart from maize which is predominately grown in the North Island.

The NZ arable industry has a farm gate value of approximately $NZ500 million. Seed exports hit a new record of $168M for the 2012 year and were made up of grass and clover seeds, seed and dry peas, forage brassica seed, specialist vegetable seed and various oilseeds produced from 65,000 ha. Approximately 50% of the production is grown under certification and 80% of the grasses and clover grown for seed are exported.

When trying to build a wish list for NZ seed producers for the next 10 years it quickly became evident that there were a number of issues that were of higher concern to growers rather than, an actual wish list. Some of these major issues will be discussed.

High yields of seed crops need to be maintained, and even improved, so that the return/ha to seed growers remains competitive with other land uses. This will require even smarter management techniques and the adoption of new technologies to keep NZ Seed Producers ahead of their competition.

The "after harvest" costs, which are paid for by the grower, appear to be continually increasing. These include seed certification and dressing charges, which are often a direct result of increases in compliance costs.

There are a significant number of new grass cultivars and types of grasses appearing in our production systems without all the necessary seed production guidelines. Too often these types are very late flowering and/or have a poor seeding ability. It will become more difficult to maintain varietal purity due to a more frequent changing of cultivars as a result of market requirements. Will we have a 'hard seed' concern in perennial ryegrass as we do with clover? Will there be more varietal testing and who will have to pay? Will we need to know more about endophyte testing and how do we maintain its viability?

The traditional use of livestock to control vegetative growth in seed crops is decreasing due to the shift away from suitable livestock types in the production areas and the requirement for later grazing in the late flowering types of ryegrass.

Once a perennial seed stand is established, can it be successfully and economically harvested for a number of years? This would help spread the establishment costs, but do we have the correct management guidelines in place to ensure a seed yield and endophyte stability.

A major issue will be the loss of certain herbicides and with the heavy reliance on glyphosate for grass weed control, potential resistant types are just around the corner. Increases in cultivation and new cultural practises will need to be developed.

The average seed loss at harvest is 12% and occurs mostly at the crop dividers. What techniques to we need to reduce this loss to less than 5%?

Some other limitations have also been identified such as lack of young/new personal in the industry and how to maintain profitability. These and further limitations are discussed and a seed producers wish list drawn is up.

Limitations to achieving higher seed yields in herbage species

Richard Chynoweth1, Thomas Chastain[2], Birte Boelt[3], Jason Trethewey[4], Nicole Anderson[5], Kenneth Svensson[6], Murray Kelly[7] and Michael Hare[8]

[1]Foundation for Arable Research, New Zealand; [2]Oregon State University, USA; [3]Dept. of Agroecology, Aarhus University, Denmark, [4]AgResearch, New Zealand; [5]Oregon State University Extension Service, USA; [6]Dainsh Advisory Service, Denmark; [7]PGG Wrightson Seeds, New Zealand; [8]Ubon Ratchathani University, Thailand

Seed yield trends for herbage seed crops have increased over time as growers adopt more precise management practices, implement more timely pest control strategies, and use equipment that is more efficient than in the past. Ultimately the major yield component is the number of saleable seeds produced per hectare and individual seed weight. However the expression of individual components of yield in alter for individual crops or plots, helps to describe how the crops achieved the seed yield outcome.

Many of the herbage cultivars in current production have been specifically bred for a non-seed production end use e.g. forage, cover crop or turf purposes, and many breeders place little importance on seed production. Of the perennial species many have the ability to produce a large number of tillers or branches, some of which remain vegetative (or have vegetative buds) to provides the perennial characteristics that make grasses common among grazed pastures, recreation and amenity areas throughout the world. The variation in age of tillers (in grasses) and the continuous emergence of flowers on a branch in many legumes creates issues for crop management, pollination harvesting and seed retention. Many herbage species exhibit a widespread flowering/anthesis curve ranging from 10 days to months. Within a flower head there is also a spread of flowering (e.g. from top to bottom (white clover) of middle outwards (ryegrass) as well as the between tiller/branch age hierarchy effect.

Yield components allow for a description of how seed yield was produced, and describe if the yield components can be compensated for by changes in other components. For example, lowered production of one yield component can be offset by an increase in production of another component without a loss in yield. This process is known as yield component compensation. The ability of some seed crops to perform well over a wide range of environments and management conditions is in part due to yield component compensation.

Grasses - focus on *Lolium perenne*

Grass seed crops are biologically inefficient in the production of seed. Many florets are produced by these grasses yet relatively few of the flowers produce a saleable seed, thus the potential seed yield may be many times greater than the actual seed yield harvested. Losses due to inadequate pollination and fertilization, abortion during seed development, development of many small seeds and seed shattering all contribute to the relative low number of seeds that are harvested compared with the crop's yield potential.

In many grasses the number of potential seed sites is large and the number of seeds set per head appears not to limit potential seed yield, at least in New Zealand, where greater than 85% of florets often contain a developing embryo at mid-late seed fill. However, often less than 30% of florets produce a seed that are large enough to become a saleable seed i.e. they are removed in the harvesting and cleaning process as a by-product of achieving high seed purity. In diploid ryegrass, the individual seed weight required is approx. 1.5 mg suggesting only the first 2-3 seeds/spikelet are large enough to be saleable. The high number of florets per spikelet (up to 12+ in Lolium spp.) is in contrast to wheat which often produces less than six and converts the majority in to saleable grain.

Grasses produce many tillers of varying ages. This leads to variation in developmental stages between tillers resulting in a spread of anthesis and harvest maturity date.The spread of tiller age at anthesis has implications ranging from difficulties with pollination, seed set, dry matter partitioning and seed shedding through to difficulties in determining agronomic input timings e.g. crop growth/development stage and harvest timings.

Often an understanding of plant physiology is used to determine if crop yield, under a certain set of circumstances, has been limited by the capacity of green tissue to generate assimilte (source limitation) or by the capacity of the harvested organs to store it (sink limitation). Organs are commonly defined as either source or sink organs when the transport of assimilate is discussed.

Warringa and Marinissen (1997), Clemence and Hebblethwaite (1984) and Chynoweth (2012) described the stem as changing from a sink to source during the 'mid seed filling' period. Therefore anything that can reduce the lag phase of seed growth or increase the rate of seed filling may increase the competitiveness of seeds as a sink. Alternatively the sink size of the stem may be reduced by stem shortening/dwarfing which may allow greater realisation of set seed to saleable seed.

The greatest opportunities to enhance seed yield through management is by increasing the number of seeds set that become saleable seed. Seed number has been shown to be increased by plant growth regulators (PGR) applications, spring nitrogen, spring irrigation, rust control and other management practices. Some management practices do increase seed weight to a small extent. The variation of seed size and weight (non-uniformity) within seed lots results in part from the position within the inflorescence where the seed was formed. This non-uniformity in seed size/weight contributes to harvest losses in the field (small seed) and to postharvest cleaning losses.

Finally the collection of mature seeds at harvest which are currently shed and would on average add 450 kg/ha of saleable seed on top of the currently achieved seed yields in New Zealand. Therefore the investigation of reduced and/or non-shedding genetics should be investigated.

Clovers

Several factors (the components of yield) contribute to the seed yield of clovers, but the aim remains to produce a large number of saleable seeds/m2 which mature at a similar time to allow successful machine harvests. Most clovers will flower over an extended period of time in relation to genetic and environmental interactions modified slightly by management factors (Figure 2).

The main factors implicated in high seed yields include:

• Flower head density (number per square metre which can be harvested)
• Flower head size (number of florets per flower head)
• Number of ovules per floret
• Ovule fertility (ability to be fertilised)
• Pollination - successful fertilisation of ovules by pollen
• Seed filling (provisioning) i.e. Growth of fertilised ovules into mature seeds

Flower head density is often the most important component of seed yield of clovers; however, compensation though larger flower heads can offset low flower head numbers (yield component compensation). In a strongly flowering white clover crop, this is primarily dependent on the number of actively growing stolon apical buds per square metre and the correct light environment for the emergence and development of the flower head from a bud.

In white clover, flower heads that blossom earlier in the season under cool conditions, are larger and bear more florets that those that blossom later at high temperatures. This result is possibly due to differentiation of the heads under cooler conditions or emergence into a less shaded environment. Flower heads tend to abort if they remain in dense canopy shade for too long after they emerge from the apical buds. Newly emerged flower heads also abort partially, or even completely, if the leaf supporting them photosynthetically is removed by topping treatments. However the next emerging flower heads during regrowth after topping and develops fully. Thus in New Zealand the environmental conditions, particularly rainfall and soil moisture in association with high fertility, during early summer can be the difference between a good and poor white clover seed crop. Methods to reduce the seasonal variation currently rely on grower experience and ‘gut feel’.

Flowers which are located on the lower half of a seed head are pollinated first and have more seeds at maturity compared with flowers at the top of a flower head. Occasionally, seed yield responses are reported when flower head numbers are stable, suggesting that the number of seeds/flower head can be manipulated if assimilate is available. For example, in New Zealand increases in seed yield have been shown at stable flower head numbers in white clover when treated with paclobutrazol.

In Oregon, similar seed yield increases have been measured when red clover is treated with trinexapac-ethyl at early stem elongation. Possible explanations include a shorter pedicel, thus allowing the seed head to attract extra assimilate from the stolons or, a shorter internode area within the stolon which has a lower storage capacity thus allowing further assimilate to be available for seed growth.

Pollination

The transfer of pollen to the stigma in clovers is achieved by insects and as such many clovers produce scented flowers and nectar. The success of pollination can range from <10% to >80% of ovules forming seed depending on flowering time, pollen production and viability, nectar production and pollinator activity. In New Zealand and Denmark white clover seed crop growers are almost solely reliant on managed honey bees for pollination. Honey bees are highly attracted to white clover seed crops and can visit individual florets multiple times, thus being highly effective pollinators. However in crops which have a long corolla tube e.g. red clover, honey bees can be inefficient pollinators which do not effectively ‘trip’ and deposit pollen as required. In this situation the bumble bees (Bombus sp.) with a long tongue are more effective pollinators but it can be difficult to manipulate their numbers within a field. However, field observations show large variations in the bumble bee population and this may be a point of interest for clover seed producers. In Oregon, red clover seed crops are largely pollinated by native bumble bees. Oregon has a large abundance and diversity of bumble bees and sometimes honey bee hives are rented but no yield differences have been measured in fields with and without honey bee hives.

Tropical species - Notes supplied by Michael Hare

1 Low seed yields. In temperate grasses, it is now common to get over 2,000 kg/ha and more in some species/cultivars. With tropical grasses it is extremely uncommon to reach 1,000 kg/ha, even with hand harvesting. Average yields range between 400-700 kg/ha for common commercial species. Very little agronomic research is taking place to improve seed production. There is little or no breeding effect being made to select or breed high seed yielding cultivars. In temperate species, considerable research effect has gone into the timing and amount of nitrogen fertiliser to increase seed yields and the timing and amount of growth regulators to prevent lodging and increase seed yields. This research is just not being done with tropical species.

2 Low seed set. In many species over 80% of seeds fail to mature. The potential is there in seed numbers but they just do not fill out. Growth regulators have been tried with no success. If these seeds could reach maturity, then 1,000 kg/ha or more is possible.

3 Low seed germination. Tropical grass seeds often only have 60-70% seed germination when traded. There are problems of embryo dormancy which can be broken by storage in some species like the Panicum sp. but not in other species like the Brachiaria sp.

4 Indeterminate flowering. Many of the tropical grasses and legumes flower and set seed over a long period-of between several weeks and up to two months in many legumes. This poses problems in deciding when to harvest. Finding ways to synchronise flowering would be very beneficial.

5 Seed crop management. Nearly all tropical pasture seed crops in Australia and South America are broadcast sown and are not planted in drilled rows like the temperate species. Some small holder farmers plant in rows. More research needs to be conducted on seed crop agronomy and management.

Plant protection and pollinators

Phil Rolston[1], Murray Kelly[2], Richard Chynoweth[3], Brad Howlett[4], Abie Horricks[4], Nicole Anderson[5], Birte Boelt[6]

[1]AgResearch, New Zealand; [2]PGG Wrightson Seeds, New Zealand; [3]Foundation for Arable Research, New Zealand; [4]Plant & Food Research, New Zealand; [5]Oregon State University Extension Service, Oregon; [6]Dept. of Agroecology, Aarhus University, Denmark

Summary

Weeds in seed crops are either competitive (reducing seed yield) or cause losses of good seed at seed cleaning because they are difficult to separate. Weeds lower seed quality and value of seed lots. Fungal diseases are common especially in grasses with stem rusts being very common and severely reducing seed yields. Insect pests especially root feeding and sucking insects are occasional problems especially in legume seed crops. Slugs are a significant problem in Oregon and is emerging problem in NZ. Managing pests and protecting pollinators are critical.
Pollinator research is focussing on pollinator species diversity to enhance seed yields. Increasing restrictions on agrichemicals requires greater attention to the principles of integrated pest management and understanding pest lifecycle's.

1. Weed Management

Weed seed contamination of seedlots is a common cause of seed quality failure. Weeds can be broadly classified as causing seed yield loss from competition during production or seed cleaning losses. A small number of species that are listed as noxious weeds or undesirable reduce the value and saleability of seedlots. Environmental regulations often reduce the choice and availability of herbicide options for weed control.

1.1 Problem weed species in grasses. Annual grass species are a constant problem in the early production years of a grass seed crop. The emergence of herbicide resistance in a number of annual grass species (e.g. In Oregon *Poa annua* resistance to ethofumesate and diuron) highlights the need for good management practices. Annual ryegrass (*Lolium multiflorium*) is a significant weed issue in perennial ryegrass (*L. perenne*). In NZ we are seeing the emergence of annual weeds that are not easily controlled with the current range of herbicides (e.g. *Vulpia* hair grass species and annual bromus species (including *Bromus hordeaceus, B. diandrus, B. sterllis*). In multi-year seed crops the problem weeds tend to shift to perennial grasses that escape herbicide treatments. Dressing loss weeds include those species when over-threshing at harvest removes awns; e.g. some annual bromes. The herbicides currently available have resulted in wild oat (*Avena fatua*) being easily managed (although resistance to fenoxaprop-P-ethyl (Puma S) is emerging; whereas volunteer cereals (wheat and barley) can cause significant problems especially in years when rains delay harvest and shorten the gap between grain harvest and autumn establishment of the new grass seed crop.

Extracting weed seed occurrence in seedlots from seed testing records provide a valuable insight into weed issues in seed crops (Rowarth et al. 1990; Alderman et al. 2013).

Grass weeds are most common problem in grass seed crops in Denmark (DK), Oregon (OR) and New Zealand (NZ) (Table 1), while broadleaved weeds are common in legumes (Table 2).

Table 1. Weeds of grass seed crops

Annual Bluegrass (*Poa annua*) (DK, OR* and NZ)
Roughstalk Bluegrass (Poa trivialis) (DK, OR* and NZ)
Bromes (ripgut, hairy chess, California, smooth chess, downy) (*Bromus* sp. (DK, OR and NZ)
Hair grass /(*Vulpi*a sp.) and Rattail Fescue Vulpia myuros (DK, OR and NZ)
Annual Ryegrass (in tall fescue and perennial ryegrass) (OR and NZ)
Volunteer Wheat (OR and NZ)
Black grass (*Alopecurus myosuroides*) (DK)
*Multiple herbicide resistance is a growing problem

Table 2. Weeds of legume seed crops

Dock (Broadleaf and Curly) *Rumex* sp. (DK, OR and NZ)
Prickly Lettuce *Lactuca serriola* (OR)
Wild Carrot Daucus carota (OR)
Plantain (Broadleaf and English) *Plantago* sp. (OR and NZ);
Field pansy *Viola arvensis* (NZ)
Sowthistle Sonchus sp. (OR and NZ)
Common Groundsel *Senecio vulgaris* (OR)
Hawkesbeard *Crepis capillatis* (NZ)
Geranium sp. (DK)
Chickweed Stelleria sp. (DK and OR)
Mayweed / Chamomile *Anthemis cotula* (OR and NZ)
Speedwell *Veronica* sp. (OR and NZ)
Nipplewort *Lapsana communis* (OR and NZ)
Annual ryegrass (multiple herbicide resistant) (OR)
Dodder *Cuscuta* (OR) and Small Broomrape (*Onobanche*)(OR and NZ) not common but invasive
Annual trifolium species *T. dubium*, *T. glomeratum* and *T. subterranean* (NZ)

1.2 The Weed Control Tool Box.
(i) Role of crop rotations. Rotations play an important role in providing fields with reduced problem weeds for the next crop and in NZ many growers can rotate between grass seed and cereals, legumes or brassica where the range of herbicides for grass weed control is wider (eg. Firebird® flufenacet) in wheat.

(ii) Herbicides are a major tool, either broadcast sprayed; applied inter-row or spot sprayed
(iii) Other tools. Precision agriculture and the use of GPS (global positioning systems) are increasing the weed control options in row crops. Advances in precision and sensing technologies for mechanical and thermal weeding systems being developed for organic crop systems have potential in conventional seed crop production.

1.3 Herbicides Resistance Management. Rotating crops and herbicide groups is essential to avoiding the induction of resistance. Grower education is essential. More difficult has been the potential of imported seed for re-multiplication introducing resistance both in the crop genetics and in weed seed contaminants.

2. Diseases

***2.1 Stem rust* (*Puccinia graminis*).** Understanding lifecycles of any pest or pathogen is a key to effective control. In Oregon this approach has led to effective predictions of stem rust infection in perennial ryegrass (Pfender et al 2009). In NZ ryegrasses and tall fescue crops have a 1/3rd rate fungicide added to the trinexapac-ethyl (Moddus) application. Locally bred early flowering forage perennial ryegrasses usually receive one further fungicide application for stem rust control; late flowering usually two applications and while overseas cultivars may require three or four depending on the year. Seed yield responses to fungicides increase NZ forage ryegrass seed yields on average by 20% while overseas turf ryegrasses are increased by 40% (Rolston et. al. 2009). In Denmark stem rust is only occasionally a problem.

2.2 Blind seed disease (Gloeotinia temulenta) and Ergot (Claviceps purpurea). In our trials we have learnt how to create environments that result in a high incidence of blind seed infection by using 2nd year or older ryegrass seed stands and creating low harvest mass (5 to 8 kg DM/ha) with short stems; e.g. no nitrogen (N) fertiliser and high rates of stem shortening plant growth regulator trinexapac ethyl (>600 g TE/ha). Triazole fungicides applied at flowering reduce blind seed infection (Chynoweth et al. 2012).

2.3 Fungicides and Endophyte Management. Integrating stem rust control and blind seed control into the same fungicide management approach has been a goal in our ryegrass seed production. While we have fungicide options that are effective for both stem rust and blind seed e.g. Proline (prothioconazole) the maintenance of desirable Neotyphodium endophytes in ryegrass and tall fescue seed offers additional challenges as some fungicides reduce endophyte transmission. Mixtures of triazole + strobiluron fungicides or strobiluron + isopyrazam are as effective in stem rust control as the best triazole fungicides, if applied early in the disease cycle.

2.4 Cocksfoot (orchard grass). In NZ seed yield increases from fungicides reducing leaf diseases (e.g. net blotch (*Drechslera dictyoides*), leaf spot (*Ramularia pusilla*) and leaf scald (*Rhynchosporium orthosporum*) have increased seed yields by 0 to 60%. Other diseases common in NZ cocksfoot include leaf fleck *Mastigosporium rubricosum*; *Cercosporidium* leaf streak or brown stripe (caused by the fungus *Scolecotrichum graminis* syn. *Cercosporidium graminis*) symptoms; stripe rust caused by *Puccinia striiformiis var dactylidis*; and anthracnose (caused by the fungus *Colletotrichum graminicola*). In some years pollen loads on leaves results in saprophyte fungi and give the appearance of disease but has little impact on seed yield. In Oregon cocksfoot production has been severely hit by choke disease (*Epichloë typhina*).

2.5 Emerging or occasional problems. High seed dressing losses (light seed) appears to be a associated with take-all disease (*Gaeumannomyces graminis var. tritici*) and Fusarium in second year crops or in first year crops with frequent rotations of ryegrass and cereals. BYDV (Barley yellow dwarf virus) spread by aphids is an increasing problem, significant in Oregon and in NZ a potential problem in crops sown in early autumn, but not in late autumn crops.

2.6 Legume diseases. Generally legume seed crop diseases are a minor or only occasional problem and can include sclerotinia, mildew, clover leaf rust and virus.

3. Pollination and Invertebrate Pests

3.1 Pollinator diversity. There is a growing awareness that pollinator diversity enhances pollination outcomes and increasing yields in crops reliant on insect pollination. Managed honey bees are essential for providing a base level of pollination, however, unmanaged native and bumble bees, and flies can enhance yields, particular in crops where honey bees are inefficient pollinators or when weather conditions limit honey bee foraging. In Oregon honey bees are used to supplement native bumble bees. Future competition for honey bee services for crop pollination and manuka honey production is likely to increase, yet long term supply of honey bees for both purposes may be restricted by honey bee specific pests and diseases. Building and sustaining on-farm unmanaged pollinator populations would reduce growers sole reliance on honey pollination.

3.2 "Trees for bees" is a on farm planting programme to provide early pollen and nectar sources to ensure honey bee numbers are strong before seed crops flower. On-farm perennial hedgerows and habitats that promote populations of known beneficial insects (pollinators and natural enemies) while minimising populations of pest species have also been designed in the programme 'Building better biodiversity on cropping farms'.

3.3 Beneficial insects and Integrated Pest Management (IPM). The enhancement of beneficial insects (ladybird, etc) and the use of bee and beneficial insect "safe" insecticides are important steps in reducing pesticide usage.

3.4 Insect pests. In NZ two native insect species cause problems porina moth an above ground winter feeder whose larvae live in the soil; and grassgrub beetles (*Coleoptera*) the larvae being autumn-winter root feeders. In legumes, sucking insects especially aphids and mirids can reduce seed yields. Some former NZ pest problems like clover casebearer moth are now effectively controlled by biological control agents. Weevils are common legume seed crops pests and including; clover seed weevils (*Apion dichroum*) in (DK/OR/NZ); clover root weevil (*Sitona lepidus*) (NZ) and alafalfa weevils (Hypera sp.) (DK). Sucking insects, aphids, mirids including Lygus bugs are common problems in New Zealand, Oregon and Denmark. The clover crown borer (*Hylastinus obscurus*) is a major pest of red clover in Oregon and no management strategies have been found.

3.5 Slugs an increasing problem. All eleven slug species in NZ are introduced species of European origin. Of these two of them are the most common slug pests of arable crops, grey garden slug *Deroceras reticulatum* (also OR) and the brown field slug, *D. panormitanum*. Slugs are a serious pest of winter wheat, white clover and ryegrass seed crop, especially during establishment and if the previous crop was process or dried peas or ryegrass seed crops following brassica seed crops. Although slugs are a more serious pest of minimum tillage, some winter wheat crops under conventional tillage are lost due to the invasion of slugs from the adjacent paddocks. Threshold slug densities for white clover and ryegrass grown as seed crops have not been established. In Oregon applications 2 to 5 times of metaldehyde and other baits are required, and bait losses to earthworms can be 25%.

Several general conclusions on the use of molluscicides, based on the published records, can be made:

- both methiocarb (4-5% ai) and metaldehyde (6% ai) bait provide effective control of slug pests in different crops when applied at recommended rates (6-10 kg/ha)
- application of molluscicide pellets by broadcasting at the time of sowing gave better control of slugs than other methods (e.g. drilling with the seed)
- the duration of the effectiveness of methiocarb and metaldehyde baits depends on weather conditions; they last for about ten days in rainfall levels of approximately 30 mm
- methiocarb baits can result in secondary poisoning of carabid beetles (generalist predators that can contribute to slug control) if beetles eat slugs that have ingested bait.

Although the recommended rates will provide control in most situations, it should be noted that in cases of very high slug densities (>100 slugs/m2), they might not be effective as all the available bait can be consumed by slugs without the slugs receiving a lethal dosage of molluscicide.

Research approaches - where next?

Jason Trethewey[1], Nicole Anderson[2], Rene Gislum[3], Yanron Wang[4], Alan Stewart[5]

[1]AgResearch, New Zealand; [2]Oregon State University Extension Service, USA; [3]Aarhus University, Denmark; [4]College of Pastoral Agriculture Science and Technology, Lanzhou University, China; [5]PGG Wrightson Seeds, New Zealand

Research approaches vary from large plots in grower's fields to detailed, highly controlled laboratory experiments. The research approach chosen is often dictated by the objectives of the investigation, time and the resources available. This review will investigate different approaches used in herbage seed research and look at the benefits and limitations of each approach. As environments change, as technology advances, as research becomes more globally linked, "where will herbage seed research be in 5 years?" Can we fuse diverse approaches together to form collective information packages? How do we use modern -omics approaches and phenotyping to aid research and benefit the grower?

Field trial scale

Field trials are important for both research and extension capability. Small plots on a research station or growers field allow for many treatments to be investigated with good replication. This approach allows for relationships between various treatments to be investigated. This approach can be easily replicated across different locations over more than one season. Small plots are useful for getting more robust datasets, testing combinations and rates and for looking at stand age variables. For example, do PGR's work on the same cultivar of a 1st year and 2nd year crop? One has control over desired inputs and can test in multiple years at the same location.

However, growers may value the benefit of small plot trials less than larger plot trials. Variation between replicates may be higher in small plots compared with larger plots, although smaller plot trials allow for hand harvesting and smaller machinery. Choosing trial locations in growers fields to overcome variables can be difficult. Plot size and the number of replicates may be limited depending upon irrigator wheel marks, fence lines, gullies, ridges and spray tracks. Large plots in grower's fields effectively demonstrate management practices and although replication is often minimised and treatments are limited, the variation can actually be lower on an on-farm large trial as compared with small plots.

Depending on the objective of the study, variables should be considered. Is the treatment being investigated going to be affected by soil type, weather from year to year, drainage, stand age, crop rotation? If so, then the trial should be replicated across those variables that matter. This type of research is more time consuming and expensive, variation will likely be higher but the data maybe more valuable than data from small plots under more controlled conditions. Communication with the grower is essential for any effective and successful grower field trial whether the approach is small or large plots.

Small versus large full size machinery approaches

Standardising sampling through the use of machinery, whether small or large plots, reduces human error and can save time. Small plot machinery combined with high replication and randomisation may reduce experimental error, although care when choosing appropriate trial sites must be taken. Small hand or motorbike mounted devices can collect large amounts of data from small areas. Although less control by researcher over management and harvest, large-scale on-farm trials are valued by growers. Growers may harvest plots themselves. This has benefits in terms of building relationships and trust between growers and researchers.

Lab based omics and links to field research

Generally, a glasshouse or laboratory experiment is a research approach where the effect of all, or nearly all, independent variables is kept to a minimum. Being highly structured this approach ensures the greatest chance against design error. Laboratory and glasshouse experiments allow the researcher to see cause and affect relationships more clearly than field based research approaches. This is because the independent variable(s), can be manipulated while keeping all other conditions that impact the dependent variable constant. However, laboratory experiments are also subject to their own limitations. This includes the artificial setting of the research that may cause changes in the dependent variable not normally seen in the natural environment.

A cross disciplinary approach may be needed to include omics research in field research. What works in the glasshouse and laboratory does not always work in nature. However, putting it together and making data-fusion may be of benefit. One of the issues is that cross disciplinary research projects can be very difficult to get financed. Another way to link lab and field based approaches is to focus on phenotyping where we include omics research and field research to show the differences and characteristics between the different plants from the glasshouse and laboratory and then in the field.

Should we think of research as both short term and long term research? Field research being short term research and omics based research being long term research. When it comes to lab vs field data we should not be afraid of putting them together and developing models to gain more collective broader knowledge.

What we should be measuring in the field?

As individual researchers, the measurements we make whether, in the lab or in the field, are determined by the research question. However, is there over-arching seed research questions that collective information may be useful in answering?

Do we measure yield as our standard with growth models based upon basic and applied research underpinning the model?

Do we require a list of potential measurements for any given research approach or area? For example, when performing nutrient research consider measuring;

- seed yield,
- nutrient content (implication of biomass and concentration),
- residual amount in soil (implications with sample depth),
- yield components,
- weather (heat units and rainfall),
- crop architecture (LAI, height),
- surrogate for N (chlorophyll meter, NIRS –reflectance measures) and
- maturity (time of anthesis, moisture at harvest, etc).

Posters Presented

In addition to the excellent talks that were given, there were 12 posters presented at the IHSG workshop. The content was very good. We encourage you to review the titles listed below and contact any of the authors if a particular topic is of interest to you.

Floret site utilisation in perennial ryegrass (Lolium perenne L.)
Birte Boelt, Simon Abel and René Gislum
Aarhus University, Denmark

New solutions for weed control in forage legumes seed production
S. Bouet[1] and F. Deneufbourg[2]
[1]FNAMS, Maison de l'Agriculture; [2]FNAMS, Impasse du verger, France

Investigations on seed retention strength in spikelets of Lolium multiflorum
Barbara Golinska and Piotr Golinski
Poznan University of Life Sciences, Poland

Effect of preparations controlling the plant ripening process on seed shedding of Lolium multiflorum
Barbara Golinska and Piotr Golinski
Poznan University of Life Sciences, Poland

Working within nitrogen limits
René Gislum, Simon Abel and Birte Boelt
Institution: Aarhus University, Denmark

Effects of row spacing and nitrogen, phosphorus applications on yield components and seed yield of *Elymus sibiricus* L
Peisheng Mao and MingYa Wang
China Agricultural University, China

Effect of trinexapac-ethyl plant growth regulator on seed yield and canopy height of red clover
Nicole Anderson, Thomas Chastain and Carol Garbacik
Oregon State University, USA

Effect of strobilurin fungicides applied at two timings on seed yield, weight and number in tall fescue
Nicole Anderson, Thomas Chastain and Carol Garbacik
Oregon State University, USA

Flowering - is it a yield limiting factor in Denmark?
Simon Abel, René Gislum and Birte Boelt
Aarhus University, Denmark

Trinexapac-ethyl application increased seed yield of diploid red clover
Dave Monks
Department of Environment and Primary Industries, New Zealand

Fungicide options for stem rust control in perennial ryegrass seed crops
Richard Chynoweth[1], Bede McCloy[2], and M. O'Hara[2]
[1]Foundation for Arable Research; [2]NZ Arable Ltd, New Zealand

Technical Support for Multiplication of International Forage Ryegrasses - PGG Wrightson Experience
M. Kelly, R. Merrilees, J. Foley, S. Butler
PGG Wrightson Seeds Ltd

Area contact people:

Oceania/Australasia – Donald Loch
lochd@bigpond.com

South Europe/Mediterranean – Gaetano Amato
amato@unipa.it

South America – Jorge Costano
jcastanio@balcarce.inta.gov.ar

North Europe – John Fairey
John.fairey@britishseedhouses.com

North America – Tom Chastain
Thomas.Chastain@oregonstate.edu

Asia – Yanrong Wang
yrwang@lzu.edu.cn

IHSG Newsletter Editor's

Jason Trethewey
jason.trethewey@agresearch.co.nz

Nicole Anderson
Nicole.Anderson@oregonstate.edu