CHAPTER 6

General discussion and conclusions

This study investigated the use of allelopathic properties from crop residues for the suppression of rye grass weed type *(Lolium multiflorum x perenne)*; evaluated the role of allelopathy from seeds, seedlings, roots and above-ground plant material of rotational crops; assessed the geographic distribution of genetic and morphological variability of rye grass and determined the interactions among allelopathic root leachates from rotational crops and rye grass on their growth rate and soil micro-organisms. With wheat fields so heavily infested, that economic grain production in certain areas will be impossible in the foreseeable future, this data will further enhance our understanding of herbicide-resistant rye grass and minimise the emergence of more species' with resistance to herbicides (Madhou *et al.*, 2005) and promote weed control measures that are alternative to herbicides.

Crop residues

Crop residues from the leguminous crops (lupine and medic) increased wheat growth with regard to plant number per m^2, yield, and plant height. The inhibitory effects of lucerne crop residues on the number of barley tillers and yield, and on plant height and yield of wheat is in accordance with those effects reported by Xuan and Tsuzuki (2002) and Xuan *et al.* (2005). Xuan and Tsuzuki (2002) and Bertholdsson (2004) reported that between and within crop species there is large genetic variation in the allelochemical content of plant tissue. Also, various studies have shown that concentrations of allelochemicals in plants are not stable. The levels of allelochemicals in a plant are influenced by abiotic and biotic stresses in combination with age or growth stage (Mwaja *et al.,* 1995; Reberg Horton *et al.,* 2005). Kruidhof (2008) described a transition from inhibitory to stimulatory effects of crop residues over time. Low concentrations of allelochemicals can stimulate plant growth (Lovett *et al.,* 1989; Belz, 2004; Belz, 2007) and increased growth has also been associated with increased nitrate levels in residue-amended soil (Henson, 1970). Therefore, the increased growth observed in some instances in the present study may indicate that there was a positive nutrient effect in conjunction with growth-promoting allelopathic activity from the crop residues. Allelopathic crops when used in rotational sequence are helpful in reducing noxious weeds, improve soil quality and crop yield (Khanh *et al.,* 2005). According to results in Experiments 1 & 2 of this study, allelopathic crops of this nature may suppress weeds without affecting wheat yield. Khanh *et al.* (2005) reported that these crop plants, particularly the legumes (*Medicago* spp), can reduce weed infestation and increase rice yield by between 20 and 70%, and are suggested for use as natural herbicides. This is congruent with most findings in allelopathy research that decomposing plant residues in soil exhibit the greatest inhibition at the early stages of decomposition and that phytotoxicity declines as decomposition proceeds (An *et al.,* 2001; Xuan *et al.,* 2005). The nature and strength of inhibitory allelopathic effects appear to be dependent on interactions between soil factors and crop residues and the allelochemicals they produce (Kumar *et al.,* 2009). Furthermore, similar to many plant characteristics, allelopathy is influenced by environmental conditions (Olofsdotter, 2002; Weston & Duke, 2003), as was experienced in Experiment 1 of Chapter 2 where high rainfall conditions could have diluted allelochemicals.

Results from Experiment 1 in Chapter 2, which demonstrated the ability of medic to suppress the rye grass weed type promise practical application under field conditions because of the crop's spreading growth habit which could be effective for the establishment of an effective organic mulch. According to results in Experiments 1 & 2, a mulch of this nature may suppress weeds without affecting wheat yield. In the case of rye grass weed type, however, both lupine cultivars suppressed the weed to only 3.9 and 4.5%, respectively. Furthermore, a suppressive plant competition effect from broadleaf weeds on the grass weeds cannot be excluded. An early flush of emergence from a huge seed bank plus high growth rates probably benefited the dominance of broadleaf weeds. In ascribing allelochemical-mediated effects under field conditions one has to be mindful of the fact that persistence of allelochemicals is largely influenced by soil type and weather conditions (Levitt *et al.,* 1984). Therefore any hypothesis based on crop residues imparting positive weed suppressive effects through the release of allelochemicals into the environment should be mindful of the fact that the practice is likely to be exposed to the vagaries of climatic (Bruce *et al.,* 2005) and edaphic factors, as well as likely being crop and weed-specific. High rainfall conditions were recorded in Experiment 1 of Chapter 2 which diluted allelochemicals, while average rainfall in 2006 & 2007 for Experiment 2 of Chapter 2 (Appendix A, Table A1) resulted in pronounced allelopathic interactions.

The optimal residue management strategy for weed suppression depends both on the nature (fine residues like those from medic are more effective as opposed to coarse residues of lupine) and amount (less residues leads to less weed control) of crop species' residues, as well as on the target weed species. Lupine gave suppression of grass weeds, giving the mulches of both leguminous crops an added benefit and their inclusion and growing in crop rotation systems with wheat and barley as main crops, more importance. However, regarding weed suppression due to allelopathic effects from crop residues, the variability in effects ascribed to variable soil and climatic factors might argue against the practice being accepted as an effective stand-alone weed control option in the foreseeable future. Partial acceptance will likely be a compromise of combining the continued limited use of herbicides with leguminous crop residues for weed control.

Plant leachates

Studies under controlled conditions are generally in accordance with those in the field (Chapter 2). The allelopathic activity observed for lupine and medic under controlled conditions, confirms that these leguminous crops should be used more frequently in the crop rotation systems of the Western Cape. Medic is already planted extensively as rotational crop in the Swartland region, but in the long rotation systems of the Overberg region, lupine should be used more frequently in the crop rotation systems used between lucerne plantings. Lupine is preferred to medic, which is a winter growing legume, as the latter is not an option in the Overberg region due to year-round rainfall which makes lucerne cultivation possible to ensure adequate grazing for the large live-stock component in agricultural production systems. Crop mulches that can provide weed control could reduce dependency on herbicides, in particular those products which are associated with the development of weed resistance. However, such a practice is likely to be exposed to the vagaries of environmental factors, as well as likely being crop and weed-specific. Results from the dry mass of rye grass, which was reduced by medic, correspond with those of

Fourie (2005) who reported that 'Paraggio' medic as a cover crop in the vineyards of the Lower Orange River had a significant negative impact on weed growth during winter. It was speculated that effectively suppressing the winter growing weeds may result in a reduction in the dosage of herbicide applied in spring, and it may minimise the negative effects caused by weeds, such as the harbouring of nematodes and insects during winter (Fourie *et al.,* 2005). Unlike medic, lupine cultivation is problematic in that a good crop stand is seldom achieved and thus negating the beneficial weed suppressive effects observed under controlled conditions. In the case of the mulch being a leguminous plant, the added benefit of nitrogen fixation will also be achieved.

Geographical variation of rye grass hybrid type

A rye grass hybrid type (*L. multiflorum x perenne*) never described before, was identified in this study. Huge genetic variation was detected between Italian rye grass weed populations with no consistently identifiable alleles among individual plants and no consistent correlation between geographical and genetic distance of specimen pairs. As no published primer pairs exist for *L. multiflorum x perenne,* no identifiable alleles associated with herbicide resistance could be identified. Nevertheless, data has indicated that there are distinct genetic groups within weedy rye grass populations of the Western Cape. Knowledge about this differentiation of rye grass could aid in the research approach on rye grass resistance and integrated control methods. In fact, knowledge of both genetic and morphological diversity may be important to guide the development of differential management of rye grass. Results from this study will further enhance our understanding of the genetics and evolution of herbicide-resistant rye grass and may lead to the development of specific and differential management strategies for weed control in each population. Although species interbreeding is most often maladaptive, it might represent an important route for the evolution of genotypes favoured under the intense selection pressure found in agricultural habitats (Tranel & Trucco, 2009). Hybridisation has been proposed as a critical stimulus for weed aggressiveness and is perhaps aiding in the evolution of adaptations critical for the success of weeds (Tranel & Trucco, 2009).

As rigid, Italian, perennial and weed hybrid rye grass occurred in the study area, it could be speculated that their responses to herbicides may display plant differential effects. Practically speaking and with herbicides registered for grass control (graminicides) grouped as controlling either annual or perennial grass species, this means that the rye grass weed hybrid may have characteristics enabling it to be tolerant to herbicides registered as annual graminicides. In that case it cannot be regarded as weed resistance to herbicides but rather as non-susceptibility, because the weed has perennial characteristics. The implication of this is that different control strategies should be devised according to the prevalent species occurring in a particular field.

The wide genetic and morphological variation detected in rye grass is interpreted on the basis of high genotypic plasticity and hybridisation for producing *Lolium multiflorum x perenne*. High levels of heterozygosity would indicate that rye grass plant populations probably have substantial amounts of adaptive genetic variations to escape the effects of a control agent. It may also be the result of the differential selection pressure or of the heterogeneity of environmental factors. Effective localised control methods for the various species and hybrids in this genus should be prioritised to curb further development of herbicide resistance.

Soils preferred by rye grass cover a wide range of fertility below and above optimum ranges for wheat and emphasises its wide adaptability and success as an invasive genus. Data on crown rot occurring on rye grass in South Africa had not been published before. Rye grass can act as alternative hosts and as a source of inoculum of this important soilborne pathogen of barley and wheat in the Western Cape Province. This further complicates sustainable dry land crop production, since the build-up of herbicide resistant rye grass may lead to a higher incidence of crown rot on wheat and barley due to a higher disease pressure. However, it could also point to a possible biological control agent for rye grass.

Effects of root leachates on micro-organisms

Plant root exudation serves as an important carbon and energy source for micro-organisms contained in the rhizosphere (Bertin *et al.,* 2003). Therefore, it is conceivable that soil microbial populations used particular carbon sources which influenced the growth rate of wheat grown on either Langgewens or Tygerhoek soils. Although the present study did not consider only the effects of allelochemicals contained in root leachates, but the combined effects of all solutes contained in them, it indicated that the effect on soil microbial population and community structure may be pronounced. This corresponds with the findings of Kong (2008) that the composition of soil microbes is defined at least in part by the nature and amount of chemicals contained in root exudates. Therefore, we contend that the growth rate of test plants in this study could be ascribed to the combination of compounds contributed by root exudates and soil microbial populations. The significantly faster growth rate of *L. multiflorum x perenne* on Langgewens soil treated with barley root leachates was revealed by PCA as a probable association with growth-promoting soil micro-organisms. In contrast, the non-significance observed for growth rate of this species on Tygerhoek soil, most probably indicates that either no growth-promoting or growth-inhibiting soil micro-organisms occurred, emphasising the importance of location in plant-microbe interactions. Furthermore, differences in plant growth rate and responses in physiological profiles of micro-organisms observed on the two soils used in the study, suggest that location is an important factor governing plant-plant and plant-microbe interactions.

Generally, the investigated plant species showed not only different plant-micro-organism associations, thus confirming results by Oberan *et al.* (2008) and Kong *et al.* (2008) who reported that different micro-organism associations exist among plant species, but results also pointed to the presence of different allelochemicals for each plant type. Kong *et al.* (2008) also reported that soil microbial populations were affected by the compounds released from allelopathic cultivars.

Comparisons between growth mediums of the leached sand in Chapter 3 and natural soil in Chapter 5 showed that results from Chapter 3 Experiment 3 were similar in terms of the inhibition of barley by leguminous crop root leachates. Wheat was stimulated by lupine in the current study, probably because effects became more pronounced after 16 weeks as opposed to the five week duration for the study in Chapter 3 Experiment 3. Lupine was stimulated in both studies, while barley root leachates inhibited rye grass v. Energa and stimulated rye grass weed type growth rate in both instances in the current study.

Gu *et al.* (2008a) and Kong *et al.* (2008) suggested that allelopathic crops and weeds could modify the microbial community structure in the soil to their advantage through the release of allelochemicals. This study strengthens the significance of soil micro-organisms in chemical root exudates and allelochemical-mediated interactions between plants, whether to lessen or to magnify effects. It has been demonstrated that not only the originally exuded compounds but also their derivatives can have allelopathic activity (Belz, 2007). Crop cultivars and weeds may modify the soil micro-organism populations to their advantage and to the disadvantage of other species by the release of root exudates that apparently differ in composition between plant species, thus confirming their allelopathic potential. Findings indicate that root exudates contained putative allelochemicals which influenced microbial community profiles. The effect on microbial communities varied with source of exudates and between soils. Changes in microbial community structure could affect plant growth through the promotion or suppression of harmful or beneficial microbes and the microbial production of allelochemicals.

Lolium multiflorum x perenne

by

Michael Ignatius Ferreira

PROMOTER: Prof CF Reinhardt

CO-PROMOTER: Dr NJ Taylor

DEPARTMENT: Plant Production and Soil Science

DEGREE: Ph.D. (Agronomy)

SUMMARY

This study investigated the use of allelopathic properties from crop residues for the suppression of herbicide resistant rye grass *(Lolium multiflorum x perenne)*, the role of allelopathy from different plant parts, the geographical distribution of genetic and morphological variability of rye grass and the interactions among micro-organisms and allelopathic root leachates. With heavily infested wheat fields, this data will further enhance our understanding of rye grass and promote weed control measures that are alternatives to herbicides. In both Experiments 1 & 2 of the field trial, growth inhibitory or stimulatory effects were observed on crops exposed to the residues of other crops. Medic suppressed *L. multiflorum x perenne* whilst lupine suppressed grass weeds. Lupine seed leachate also reduced wheat cumulative germination. The radicle length of rye grass was inhibited by seed leachates from wheat and lupine. This growth-inhibiting effect from lupine seed and seedling leachates was also evident in rye grass radicle length and cumulative germination percentage. Morphologically, 50% of the total number of specimens was classified as rigid rye grass, 48% as the hybrid, namely *L. multiflorum x perenne* and 2% as perennial rye grass. *Fusarium pseudograminearum* (crown rot) was isolated from rye grass at six localities, indicating that this weed complex can act as alternative hosts and a source

of inoculum of this important soil-borne pathogen. On Langgewens soil, the growth rate of wheat was stimulated by lupine (v. Tanjil or v. Quilinock). The faster growth rate of rye grass on Langgewens soil treated with barley root leachates was revealed by Principal Component Analysis (PCA) as a probable association with growthpromoting soil micro-organisms. Results from the field for medic on the suppression of rye grass weed type growth promises practical application under field conditions because of the crop's preading growth habit which could be effective for the establishment of effective organic mulches. Studies under controlled conditions confirmed effects of leguminous crops in the field. The wide genetic and morphological variation detected in rye grass may be due to high genotypic plasticity and hybridisation for producing the weed type *L. multiflorum x perenne*. Effective localised control methods for the various species and hybrids in this genus should be prioritised to curb further development of herbicide resistance. Crop cultivars and weeds may modify the soil micro-organism populations to their advantage and to the disadvantage of other species by the release of root exudates that apparently differ in composition between plant species. The effect on microbial communities varied with source of exudates and between soils.