SUMMARY

Currently, global food prices are on the increase and it is reaching values higher than in 2008, forcing those who spend half of their income on food into poverty (Parker, 2011). In future, food production will have to increase to meet the higher demand because of the rise in the global population. This will be more difficult than during the Green Revolution in the 1960s due to the reduced availability of land and water resources and policies regarding fertilizer and pesticide use. With the pressure of sustainable food production in environmentally benign ways, and the recent surge in crop production input costs on a global scale, crop producers are compelled to change or adapt current production systems. In South Africa, previous unsustainable crop production practices have contributed to a decline in soil stability, leading to topsoil losses, and therefore fertile production areas. Land users are obliged by law to adhere to the Conservation of Agricultural Resources Act of 1983 to conserve natural resources, by among other things, combating and preventing soil erosion and maintaining the production potential of the soil. For achieving these goals, methods such as conservation tillage, suitable conservation works, avoidance of cultivation during periods of high erosion hazard and the inclusion of cover crops in their cultural practices, are advised.

Weed interference is a given in any crop production situation, leading to potentially high yield losses if weeds are not adequately controlled. With the introduction of herbicides, producers were able to simplify their weed management with the added advantages of it being reliable, effective and relatively inexpensive. This created the impression that weed control was fairly undemanding. The focus therefore shifted from a long-term weed management strategy aiming to reduce weed density through cropping systems, to the reliance on chemical weed control directed at controlling weed seedlings just prior to, or shortly after crop establishment. Reliance on chemical control only, has drawbacks, such as the development of herbicide resistance, the potential negative impact on food and environmental safety and the failure to control

weeds due to adverse climatic conditions or application errors. Therefore, weed management should focus not only on curative methods but instead on combining different cultural methods to prevent and manage weed populations. Cultural weed management includes any adjustments or modifications to production practices that would improve crop competitiveness and reduce weed density such as manipulating plant populations and planting dates, using crop cultivars adapted to the climatic conditions, including different crop rotations and using cover crops in combination with conservation tillage, to mention a few. Cover crops not only improve soil conditions, but can suppress weed establishment and growth thereby reducing weed populations to a level below the threshold value where weeds start to interfere with crop growth. This is achieved through changes in the growth environment such as excluding light reaching the soil surface, creating a physical barrier and through the release of allelochemicals from the cover crop residues. The question that needs to be asked is whether cultural practices will be able to provide a substantial contribution to weed management.

Research has been done on various aspects of conservation tillage in KwaZulu-Natal (KZN), but research on the use of cover crops in a crop production system for weed control is lacking. Information and an understanding of the ability of cover crops to suppress weed growth and the subsequent effect on crop growth in a conservation tillage system are vital if principles were to be developed on the use of cover crops for weed management in KZN. Based on the knowledge generated, farmers can be assisted in the implementation of supplemental weed control methods as weed management is a difficult aspect of conservation tillage. If proven effective, the use of cover crops, alone or in combination with herbicides, can in the long term prove not only to be more economical as less herbicides could be used, thereby lowering the chemical input costs, but also contribute to a more environmentally balanced crop production system. In KZN, maize (*Zea mays*) is the most important grain crop and contributes to 4.6% of the total maize production in South Africa. As is the case in the rest of the world, *Cyperus esculentus* (yellow nutsedge) is one of the most difficult weeds to control and in a conservation tillage system it, among others, can become a dominant and difficult weed to manage if weed control is ineffective (Fowler, 2000). A research project was implemented in KZN to test the hypothesis that cover crops would suppress *C. esculentus* growth without compromising the growth of maize.

In a field experiment done over four consecutive years with two cover crops, stooling rye (*Secale cereale*) cultivar 'Agri-Blue' and annual ryegrass (*Lolium multiflorum*) cultivar 'Midmar', maize emergence was suppressed by the residues of both cover crop species compared to treatments without any residues. For 14 days after emergence (DAE), early maize growth was similar between all treatments, regardless of the presence of cover crop and weed residues on the soil surface. Thereafter, maize growth was suppressed by the residues compared to non-residue treatments. Despite both cover crops having similar amounts of biomass on the soil surface, annual ryegrass suppressed maize growth more than stooling rye residues. *C. esculentus* growth was severely inhibited in the inter-row maize planting lines by annual ryegrass residues for 14 DAE, whereafter the growth suppression progressively diminished. Although stooling rye suppressed *C. esculentus* growth to a lesser extent than that of annual ryegrass, the suppression lasted longer. Results also indicated that growth seasons had a significant impact on the ability of the cover crops to suppress crop and weed growth, with more suppression occurring during warm, wet conditions rather than under warm/dry and cold/wet conditions.

Physical obstruction by the residues did not influence maize emergence but the possibility of lower soil temperatures underneath the cover crop mulch could have suppressed emergence leading to lower maize plant populations. The main cause of maize and *C. esculentus* growth suppression is however attributed to the release of allelochemicals from the cover crop residues. Although no maize growth differences were seen between the different treatments for 14 DAE, it is likely that during this time, the maize seedlings absorbed allelochemicals released by the cover crop residues, thereby reducing their fitness. Also, the cover crop residues suppressed *C. esculentus* growth, thereby reducing competition with maize for resources. However, after 14 DAE, *C. esculentus* growth increased to such an extent that the threshold value was reached where competition for growth resources started to impact negatively on maize seedling growth. Despite fierce *C. esculentus* competition in the weeds treatment due to higher *C. esculentus* densities, maize growth reduction in this treatment was less compared to the cover crop treatments as maize growth was not compromised by the presence of allelochemicals leached from the cover crop residues. Maize seedlings in the cover crop residues could not recover from the influence of allelopathy and *C. esculentus* competition, which culminated in significantly lower maize yields. It is further possible that the difference in the allelopathic potential of the two cover crops was responsible for the difference in their effect on maize seedling growth.

In order to seek confirmation of the allelopathy-based hypothesis, an investigation on the influence of different cover crop species and residue types on maize and *C. esculentus* emergence and growth under controlled conditions, was initiated. Cover crops selected included those used in the field trial namely stooling rye, cultivar 'Agri-Blue' and annual ryegrass cultivar 'Midmar', together with oats (*Avena sativa*) cultivar 'Heros' and two additional annual ryegrass cultivars 'Agriton' and 'Sophia'. Oats was included as it is known for its weed control abilities (Campiglia *et al*., 2010), while different annual ryegrass cultivars were evaluated due to possible cultivar differences in their allelopathic potential. The cover crops were sown in pots according to field-recommended seeding rates and grown for 21 weeks, whereafter plants were killed by spraying them with glyphosate-isopropylamine. Two weeks after killing the cover crops, maize seeds and *C. esculentus* tubers were planted into pots containing different types of cover crop residues. These residues included both cover crop leaf and roots left intact in the pots, and only root residues left undisturbed in the pots. The leaf material collected from the pots containing only root residues were then placed on previously unused sand to eliminate the possible influence of the root material. An equal portion of the same leaf material was soaked overnight in water before being placed on unused sand.

Confirmation was obtained that differences in maize emergence in the field experiment was not due to a physical obstruction. Maize emergence was not influenced by the different residue types while *C. esculentus* emergence was severely inhibited by treatments containing root residues. Overall, annual ryegrass residues suppressed maize and *C. esculentus* seedling growth the most while oats and stooling rye had similar but lesser effects. Cultivar differences were observed with the cultivar 'Midmar' being the most suppressive followed by 'Agriton' and 'Sophia'. With regards to residue type, the root residues inhibited growth the most followed by the leaf+root residues. Growth was the least affected by the two leaf material treatments although the influence of the unsoaked leaf material treatment was confounded by unexpected glyphosate-isopropylamine damage as a result of the herbicide being absorbed by maize and *C. esculentus* developing through the cover crop residues killed by the herbicide. It was further evident that by soaking the leaf material overnight in tap water, the suppressive qualities of the leaf material were reduced, which pointed to allelochemicals having been present in the leaf material prior to soaking. The soaking could also have removed glyphosate residues from the leaves, improving maize growth.

Chemical analysis of the leachate collected from the root material of the three annual ryegrass cultivars and oats indicated the presence of two known phenolic allelochemicals, ferulic and p-hydroxybenzoic acid as well as the benzoic acid benzoxazolin-2(3*H*)-one (BOA). Because BOA is released from 2,4-dihydroxy-1,4 benzoxazin-3 one (DIBOA) during decomposition of residues, or through root exudation (Chiapusio *et al.*, 2004), the cover crop species tested would probably contain DIBOA as well. Difference in allelochemical content was established amongst the cover crop species and cultivars with 'Midmar' having the highest concentrations of BOA and p-hydroxybenzoic. Results of the pot trial confirmed for the first time the presence of three known allelochemicals in annual ryegrass as well as concentration differences amongst annual ryegrass cultivars. This could explain the higher growth inhibition of maize and *C. esculentus* when exposed to 'Midmar' residues compared to the other cover crop species.

The allelopathy-based hypothesis was therefore confirmed. The findings suggest that the growth of difficult-to-control weeds could be suppressed by allelopathic cover crops in a maize conservation tillage system in KZN but that crop growth was at risk. It is therefore possible that with the use of cover crops, the growth of other weed species could be suppressed as well. Principles regarding the use and management of cover crops would have to balance the weed growth suppression gained by the residues with minimizing the reduction in crop growth.

To reduce the negative influence of cover crop residues on crop growth, various options could be considered. The degree of crop growth reduction is dependent on the cover crop species and cultivar. By evaluating different cover crop species and cultivars, a combination could be selected that would optimize weed growth and minimize crop injury. Killing the cover crop at planting of the main crop could reduce the risk to crop growth as seedlings would be exposed to initially slow allelochemical release from relatively fresh residues, resulting in lower allelochemical concentrations in the root zone during the vulnerable seedling stage. Subsequent crop seedling growth could further be enhanced by planting cultivars with a vigorous growth habit, adapted to local soil and climatic conditions. Exposing the crop to minimal cover crop residues in the planting line could also lessen the impact on crop growth. If the residues were removed from the planting lines, for example by practising strip-tillage, the allelochemical content in the root zone would be lower, thereby reducing the negative influence on crop growth.

Weed suppression is mainly determined by the cover crop species and cultivar. It not only influences the period of residue decomposition and subsequent availability of allelochemicals, but also the potential concentration of allelochemicals which is a function of the biomass production capabilities of the cover crop species and cultivar. Ideally, allelochemicals must be released from the residues over an extended period to prolong weed growth reduction. The soil and climatic conditions would also determine allelochemical release from the decaying residues and the allelochemical concentration in the root zone, thereby impacting on the degree of weed growth suppression. Manipulation of the cover crop killing date could extend the period of weed suppression due to the prolonged presence of the residues on the soil surface, but the subsequent negative influence on crop growth could also be increased. Although cover crops can provide a substantial contribution to weed management, in order to achieve prolonged, effective weed control, the combination of cover crop residues on the soil surface and the application of herbicides will probably be required. It could for example result in pre-emergence herbicide application to the planting rows only instead of broadcast applications or chemical control could be restricted to post-emergence herbicide use. Using glyphosate tolerant cultivars could also be beneficial, with weed control being less complicated. The extent to which herbicides will be used is dependent on the degree of weed suppression achieved by the cover crop residues.

Certain constraints and barriers, however, limit the adoption and implementation of cover crops in a weed management system. No ready-to-use technology for allelopathy mediated weed prevention and control can be given to farmers. Recommendations will have to be based on their management level, cultural practices used, climatic and soil conditions, economic considerations and social requirements. The practice is not ideal for the rural areas of KZN due to the communal land tenure system which limits the right of the farmer to the use of the land to the season the crop is grown. After the crop is harvested, the fields are used for grazing, making the use of cover crops impossible. The involvement of various crop production systems also increases the complexity of the weed management system for both small-scale and commercial farmers.

In conclusion, the use of cover crops for weed control should be considered a tool that is supplementary/complementary to standard weed control practices aiming at managing weed populations in the long-term. The principles are not restricted to KZN, but can be applied to the rest of South Africa. Future research should include the evaluation of the weed suppression abilities of different cover crop species and cultivars, the influence on crop and weed growth through manipulation of the cover crop killing date and the evaluation of different herbicide application times and rates. A question that needs to be answered is whether the main crop could recover adequately, producing acceptable yields, after being exposed to the cover crop residue in the root zone if weed competition is limited.

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