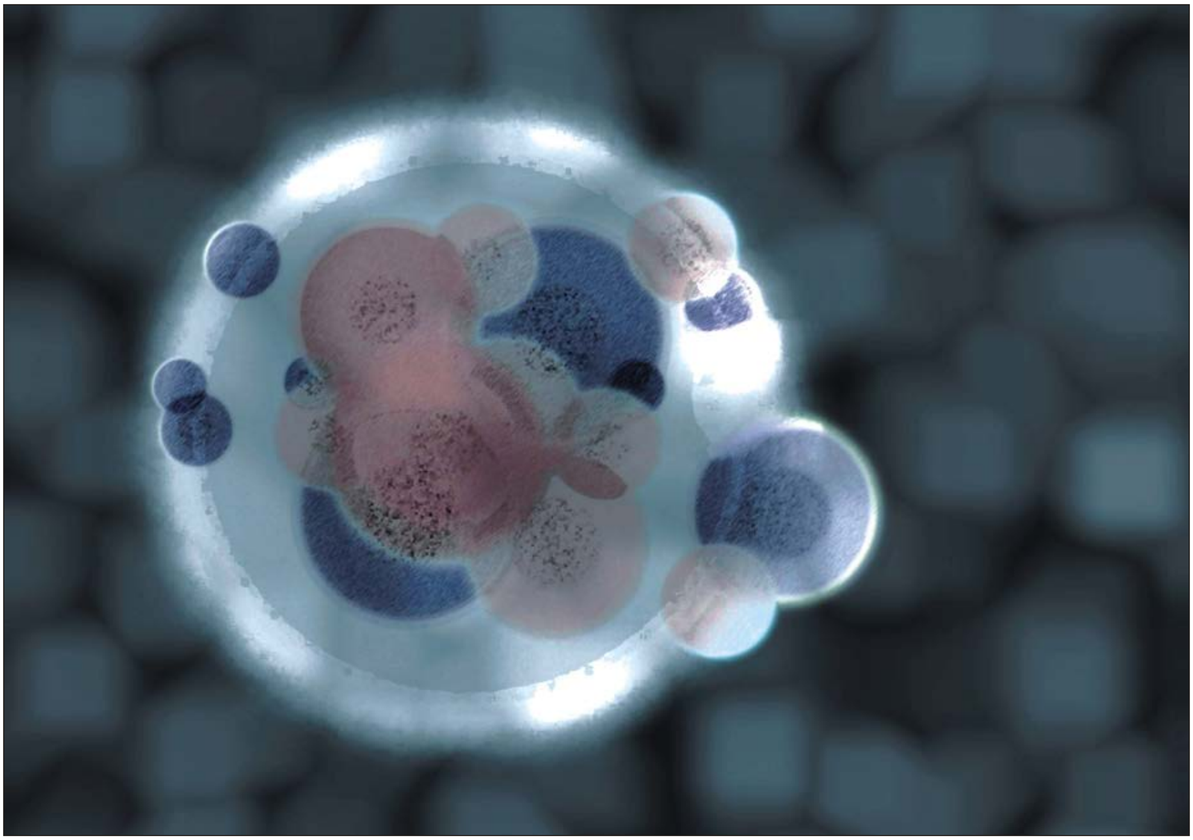

Journal of Biological Sciences

ISSN 1727-3048

Journal of Biological Sciences 14 (7): 452-459, 2014
ISSN 1727-3048 / DOI: 10.3923/jbs.2014.452.459

Mechanisms of Ecological Weed Management by Cover Cropping: A Review

Fikre Lemessa and Mulatu Wakjira
Department of Horticulture and Plant Sciences, College of Agriculture and Veterinary Medicine,
Jimma University, P.O. Box 307, Jimma, Ethiopia

Abstract: Weeds are important biotic constraints in agroecosystems that interfere with crop plants and consequently reduce yield and quality of crops. An estimated world-wide crop yield loss of about 43% was reported when weeds are left uncontrolled. Agricultural intensification since the 1940s mainly focused on heavy reliance on chemical herbicides to control the weed problem. Nowadays, this is considered objectionable due to the potential negative impacts of herbicide compounds on food safety, non-target organisms, beneficial species, public health and the environment and development of herbicide resistant weeds. Therefore, systems-oriented approaches to weed management that make better use of alternative weed management tactics which are compatible with a specific production system need to be developed. One of such approaches is the use of plants with strong weed-suppressing ability as a component of integrated crop management. Cover crops are well-suited in such holistic approach as they provide many other agroecosystem services besides suppressing weeds. Living cover crops suppress the development of weed populations through niche pre-emption. Moreover, cover crop residues suppress or retard weed emergence and growth due to both allelopathic and physical effects. In this study, major mechanisms were reviewed through which cover crops serve as ecological weed management.

Key words: Allelopathy, cover crop residues, living cover crops, weed suppression

INTRODUCTION

Weeds are important biotic constraints in agroecosystems that interfere with crop plants, through competition and allelopathy and consequently reduce yield and quality of crops (Bastiaans *et al*., 2007; Morvillo *et al*., 2011; Ali *et al*., 2014). Evidently, an estimated world-wide crop yield loss of about 43% was reported when weeds are left uncontrolled (Oerke, 2006). To overcome the negative effects of weeds on the crop production, a number of weed management methods have been employed since the beginning of agriculture (Bastiaans *et al*., 2008). However, agricultural intensification since, the 1940s has mainly focused on the use of synthetic chemical herbicidesto control the weed problem. Nowadays, this is considered objectionable due to the potential negative impacts of herbicide compounds on food safety, non-target organisms, beneficial species, public health and the environment and development of herbicide resistant weeds.

Weed suppression is one of the services provided by cover crops to the agroecosystem. As a result, there is an increasing interest in the use of cover crops in agriculture (Samedani *et al*., 2014; Didon *et al*., 2014). The degree of weed suppression provided by cover crops depends on the cover crop species, residue biomass, weed species and environmental factors (Liebman and Mohler, 2001). Cover crops suppress weeds either in the form of living plants or as left on the soil surface or incorporated residues. Living cover crops suppress the growth and development of weeds through niche pre-emption by filling the spaces and essential resources in the cropping systems that would otherwise be occupied and utilized by the weeds (Liebman and Mohler, 2001). These growing cover crops prevent the emergence, growth, development and seed production of weeds through competition for essential resources such as water, nutrients and light and through allelopathic mechanisms (Bastiaans *et al*., 2007). On the other hand, cover crop residues left on the soil surface as mulch or incorporated into the soil inhibit or retard the germination, emergence and early growth of the weeds (Kruidhof *et al*., 2009). Cover crop residues can inhibit emergence of weeds by attenuating environmental cues, physically interfering with emergence and releasing allelopathic compounds (Teasdale *et al*., 2007).

Cover crops interfere with the development of weed populations through two important mechanisms (Kruidhof *et al*., 2008, 2009). First, introduction of cover crops into the agroecosystem prevents growth and development of weeds through niche pre-emption (Liebman and Mohler, 2001; Kruidhof *et al*., 2008). In this case, cover crops occupy the space and utilize the resources that would otherwise available to weeds. Second, incorporated or soil surface-placed cover crop

Corresponding Author: Fikre Lemessa, Department of Horticulture and Plant Sciences,
College of Agriculture and Veterinary Medicine, Jimma University, P.O. Box 307, Jimma, Ethiopia

residues can inhibit or retard germination and establishment of weeds (Ohno *et al.*, 2000; Kruidhof *et al.*, 2009). Cover crop residues used as surface mulches, suppresses or retards weed germination, emergence and growth due to both allelopathic and physical effects (Liebman and Davis, 2000). Incorporated residues of allelopathic cover crops can also inhibit or retard germination, emergence and growth of weeds. For this purpose, cover crops that have a high level of allelochemicals seem to be well-suited (Kruidhof *et al.*, 2009).

Besides physical and allelopathy-mediated weed suppression, there are many other mechanisms through which cover crop residues affect weed germination and establishment (Kruidhof *et al.*, 2009). Nutrients released from the cover crop residues mainly nitrogen can stimulate weed seed germination (Teasdale and Pillai, 2005) whereas temporary immobilization of nitrogen as a result of slow decomposition rate of high C/N cover crop residue decomposition can inhibit germination (Liebman and Mohler, 2001). Soil surface-placed residues can result in less fluctuation in soil temperature and physically reduce penetration of light, both of which have been demonstrated to inhibit germination (Liebman and Mohler, 2001). Moisture may be better conserved when soil is amended with cover crop residues (Teasdale and Mohler, 1993). Furthermore, soil amendment with fresh residue material may in some cases either stimulate (Manici *et al.*, 2004) or suppress (Matthiessen and Kirkegaard, 2006) the multiplication and activity of soil microbes which have an impact on weed seed bank.

Cover crops play a key role in ecological weed management through the above mentioned two mechanisms. 'Ecological/cultural weed management is any adjustment or modification to the general management of the crop or cropping systems design that contributes to the regulation of weed populations and reduces the negative impact of weeds on crop production' (Bastiaans *et al.*, 2008). Ecological weed management mainly rely on three principles (Bastiaans *et al.*, 2008): (1) A reduced recruitment of weed seedlings from the soil seed bank, (2) An alteration of crop-weed competitive relations to the benefit of the crop and (3) A gradual reduction of the size of the weed seed bank. In this study, the contribution of the use of living cover crops and cover crop residues towards these three principles and how they generally play role in weed suppression are studied (Fig. 1).

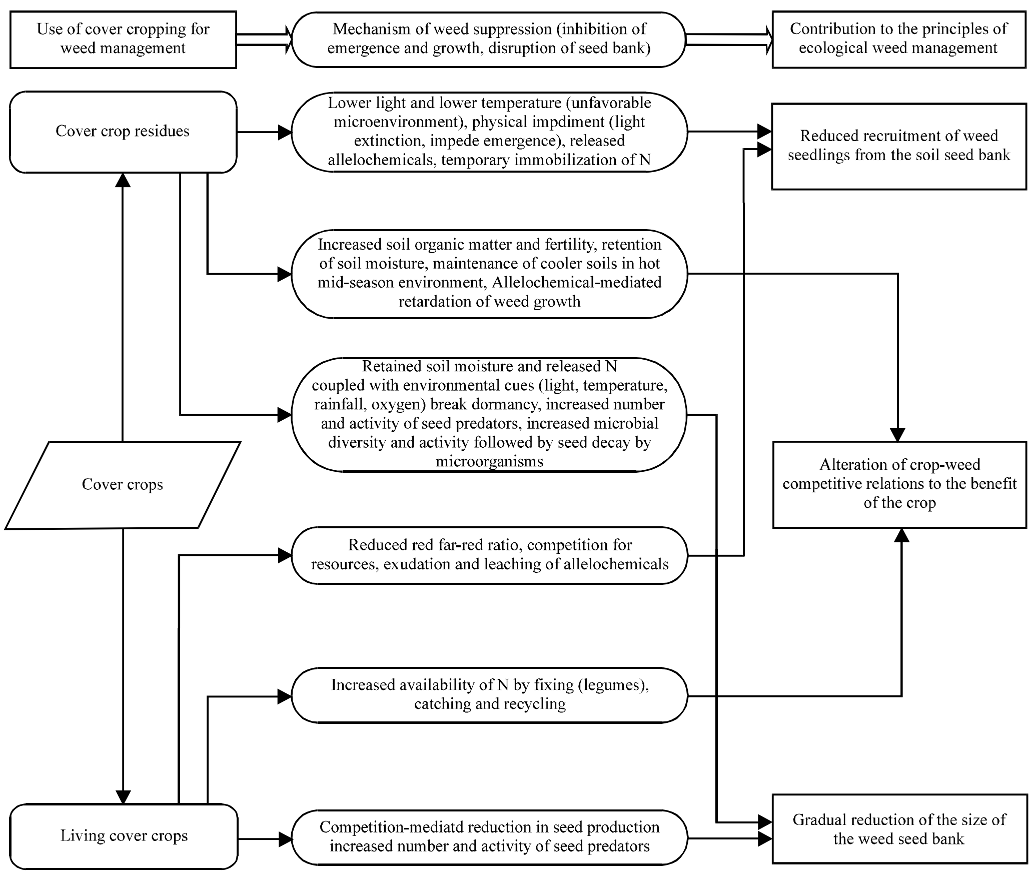

Fig. 1: Contribution of cover crops to ecological weed management

LIVING COVER CROPS

Cover crops during their growing phase, living cover crops, can be used as living mulches to suppress weeds in agroecosystems. Vigorously growing living cover crops suppress weeds that are growing during the same time and at the same place (Akobundu *et al*., 2000; Creamer and Baldwin, 2000; Blackshaw *et al*., 2001; Favero *et al*., 2001; Grimmer and Masiunas, 2004; Peachey *et al*., 2004; Brennan and Smith, 2009). Living cover crops prevent growth and development of weeds through niche pre-emption (Liebman and Mohler, 2001; Kruidhof *et al*., 2008). Weeds are suppressed by living cover crops either through competition-mediated reduction of resource availability such as access to light, nutrients and water (Ngouajio and Mennan, 2005), mechanical or physical hindrances (Den Hollander *et al*., 2007), or allelopathy-based inhibition of weed germination, emergence and early growth (Reberg-Horton *et al*., 2005). Living cover crops also affect persistence of weeds (Ngouajio and Mennan, 2005) and weed flora composition (Wright *et al*., 2003) as they influence access to light, nutrients and water (Linares *et al*., 2008).

Living cover crops generally create unfavorable radiation environment for weed germination, emergence and growth, reduce light with red to far-red ratio and high daily temperature amplitude, compete for light, water and nutrients and release allelochemicals that inhibit or retard germination, emergence and early growth (Teasdale, 2003). Phytochrome-mediated seed germination is sufficiently inhibited by a living cover crop than cover crop residues as the living cover crops absorb red light and reduce the red to far-red ratio whereas cover crop residues have less impact on the red to far-red ratio (Teasdale and Daughtry, 1993; Hassannejad and Mobli, 2014). Through all these mechanisms, living cover crops reduce recruitment of weed seedlings from the soil seed bank.

Living cover crops also increase the nitrogen available to plants through nitrogen fixation (legumes), catching unused nitrogen and nitrogen recycling and hence the available nitrogen play in the alteration of crop weed competitive relations towards the benefit of the crop resulting in improvement of the competitiveness of the crop over the weeds (Teasdale *et al*., 2007). Living cover crops can also significantly reduce seed production if growth and development are sufficiently suppressed (Brainard and Bellinder, 2004; Brennan and Smith, 2009). In this regard, the degree of reduction in growth and development attributed to the living cover crops is highly correlated with the extent of reduction in weed seed production (Brennan and Smith, 2009). Living cover crop vegetations also enhance weed seed mortality by increasing seed predation through increased diversity and activity of predators (Davis and Liebman, 2003; Gallandt *et al*., 2005). Living cover crops hence gradually reduce the weed seed bank size.

A mechanism that provides continuous and adequate weed suppression throughout the life cycle of weeds (seed/vegetative reproductive structure to seed) is preferred for use in agroecosystems. Cover cropping generally influence weed populations at multi-sages in the life cycle of weeds. These include preventing or reducing production of propagules, reducing seedling establishment which is a function of germination, emergence and growth and minimizing successful establishment of individual weeds through negatively influencing their competitive ability (Gallandt *et al*., 1999). In this respect, depending on whether the cover crop is acting during its growing phase or as residue, different life stages of weeds are affected (Fig. 2). Living cover crops

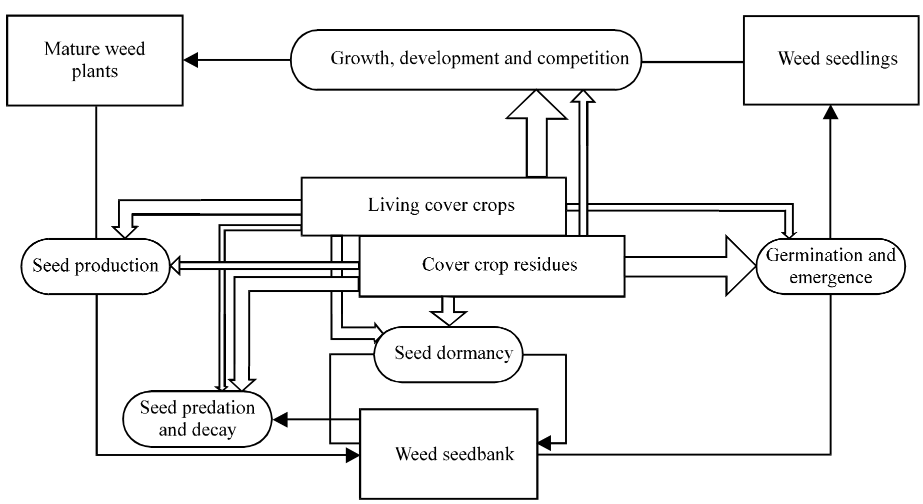

Fig. 2: Impacts of living cover crops and cover crop residues on weed life cycle

suppress weeds more strongly and consistently at almost all phases of the weed life cycle than cover crop residues because living cover crops compete for essential resources with growing weeds throughout the life cycle of weeds (Teasdale and Daughtry, 1993; Reddy and Koger, 2004; Brennan and Smith, 2009; Teasdale *et al*., 2007). In conclusion, living cover crops greatly suppress growth, development and competitive ability of the weeds and seed production than cover crop residues (Fig. 2).

COVER CROP RESIDUES

Cover crop residues generally suppress weed germination, emergence and early growth by modifying the microenvironment of the germinating seed that includes light, temperature, moisture and chemicals (Teasdale *et al*., 1991). Emergence and growth of weeds can also inhibited or stimulated through changes in nitrogen dynamics, by temporary immobilization or release of nitrogen, respectively, as a result of cover crop residues (Kumar *et al*., 2008). Cover crop residues reduce recruitment of weed seedlings from the soil seed bank creating unfavourable microenvironment, physical extinction of light and impedement of seedling emergence, releasing inhibitory allelochemicals and temporary immobilization of nitrogen (Teasdale, 2003; Teasdale *et al*., 2007). In addition, competitiveness of the crop is improved by cover crop residues through incresing soil organic matter and fertility, retention of soil moisture, maintenance of cooler soils in hot mid-season environment and allelochemical-mediated retardation of weed growth (Teasdale, 2003). Furthermore, cover crop residues gradually reduce the weed seed bank size by retaining soil moisture coupled with environmental cues that lead to breaking dormancy, increased diversity, number and activity seed predators; and micobes that play key roles in seed decay (Teasdale *et al*., 2007).

Cover crop residues can be used in suppression of germination and establishment of weeds either left on the soil surface as mulch or after incorporated into the soil (Ohno *et al*., 2000; Kruidhof *et al*., 2009).

Soil surface-placed cover crop residues: Cover crop residues in this case are left on the soil surface as dead mulch. Physical characteristics of soil surface-placed residues such as area to mass ratio, solid volume fraction, light extinction coefficient and decomposition rates can influence the degree of suppression posed on germination, emergence and early growth of weeds (Teasdale and Mohler, 2005).

When cover crops are placed on the soil surface, suppression of weed germination and emergence can be provided by absence of tillage that avoids exposure to light (Teasdale, 2003). Soil surface-placed cover crop residues can also retard germination, emergence, early growth and density of weeds by physically impeding downward penetrating light required for germination and early photosynthesis and upward emerging seedlings and by releasing allelochemicals (Teasdale and Mohler, 1993, 2005; Yenish *et al*., 1995; Blackshaw *et al*., 2001; Bond and Grundy, 2001; Moonen and Barberi, 2006; Kruidhof *et al*., 2009). In addition, soil surface-placed cover crop residue-mediated inhibition of weed seed germination, emergence and growth could be by lowering daily temperature amplitude (Teasdale and Mohler, 1993). Furthermore, cover crop residue dead mulches increase soil organic matter and fertility that improve growth and vigor of crop plants and hence their competitive suppression of weeds (Teasdale *et al*., 2004).

Soil surface-placed cover crop residues also influence soil microbial ecology and hence enhance microbial diversity on or near the soil surface that leads to enhanced weed seed predation and decreased weed vigor (Gallagher *et al*., 1999; Ngouajio and McGiffen, 2002; Gallandt *et al*., 2005) or may influence population dynamics of weeds (Jordan *et al*., 2000). However, cover crop residues have no influence on the survival of perennial structures such as rhizomes, tubers, bulbs and creeping roots (Akobundu *et al*., 2000). Contrarily, surface-placed cover crop residues can enhance emergence of weeds by retaining soil moisture and releasing nitrogenous compounds that interact with environmental cues such as exposure to light, high alternating daily temperature amplitude, imbibed soil moisture and dissolved oxygen that break dormancy and as a result reduced weed seed bank size (Teasdale and Pillai, 2005).

Soil-incorporated cover crop residues: Cover crops are incorporated into the soil to suppress weed by inhibiting or retarding germination, growth of radicle and plumule following germination and retarding emergence of seedlings and early growth (Sarrantonio and Gallandt, 2003). Incorporated cover crop residues mainly contribute to weed suppression by physical impediment and release of allelopathic compounds. Decomposition of soil-incorporated fresh cover crop residues produce wide array of allelopathic compounds or pathogens that inhibit germination, emergence and early growth (Dabney *et al*., 1996; Blackshaw *et al*., 2001; Davis and Liebman, 2003; Sarrantonio and Gallandt, 2003). Allelopathic compounds from incorporated cover crop residues inhibit or retard weed root and hypocotyl growth immediately after germination and retard seedling emergence (Teasdale *et al*., 2007). However, soil tillage used to incorporate cover crop residues can stimulate germination and emergence of weed seeds that require light for germination (Teasdale, 2003). In addition, release of nutrients during residue decomposition stimulates germination (Teasdale and Pillai, 2005).

The degree of weed suppression provided by the incorporated cover crop residues depends on the rate of decomposition which is related to the quality of the residue, on the quantity of the residue, on the amount of tissue disruption before incorporation and the environmental factors (Cheng, 1992; Liebman and Mohler, 2001; Kruidhof *et al*., 2009). For instance cover crop residues with high C/N ratio decompose slowly and release allelochemicals at slower rate and hence lower early but extended weed suppression (Teasdale and Mohler, 1993). Regarding quantity, the higher the quantity of cover crop residue incorporated the higher the degree of inhibition posed on annual and broadleaved weeds (Buhler, 1996; Crutchfield *et al*., 1986). Methods of shredding such as chopping and grinding that thoroughly disrupt the cover crop residue tissue lead to faster decomposition and release of the allelochemicals and hence faster rate of inhibitory effects (Kruidhof *et al*., 2009). Decomposition rates are also higher under warm tropical conditions than temperate climates.

Compared to soil surface-placed cover crop residues, incorporated residues mainly inhibit germination, emergence and early growth (Teasdale, 2003; Teasdale *et al*., 2007) (Fig. 2). Weed emergence is more affected than weed density or biomass by allelochemicals from incorporated cover crop residues. This is because allelopathic inhibitory effects of cover crop residues cannot persist for more than two weeks after residue incorporation (Teasdale *et al*., 2007; Kruidhof *et al*., 2009). Weed suppression after this period is more of physical effect than allelochemical-mediated (Teasdale *et al*., 2007). Hence, cover crop residues have a negligible impact on weed growth and seed production once weed seedlings become established; rather, they even stimulate these processes through conserving soil moisture and releasing nutrients (Teasdale and Daughtry, 1993; Haramoto and Gallandt, 2005).

ROLE OF ALLELOPATHY

One mechanism through which cover crops, both living and cover crop residues, play a key role in weed suppression is by releasing secondary metabolites called allelochemicals and the mechanism of suppression is referred to as allelopathy. 'Allelopathy is defined as the biochemical interaction between one plant or microorganism and another plant through the production of chemical compounds called allelochemicals mainly of secondary metabolites which exert direct or indirect, inhibitory or stimulatory, effect on plant growth and development' (Rice, 1984). The use of allelopathic cover crops for suppressing weeds is an important method of ecological weed management (Sullivan, 2003) and if other competitive factors are balanced, allelopathy can play an important role in cover crop-based weed suppression (Fujii, 2003). Suitable use of allelopathic cover crops in agroecosystem reduce pesticide use and thereby reduce environmental and food pollution and increase biodiversity and sustainability of agroecosystems (Kalinova, 2010).

Allelochemicals could be released to the environment as volatiles from leaves, stem, flowers, root exudation, leachates from aerial parts (by dew, fog or rain drip) and decomposition of residues followed by physical and/or chemical transformation and biodegradation (Kalinova, 2010) (Fig. 3). The suitable allelopathic effects on the target weed include inhibition of germination, reduced growth, swelling and necrosis of roots, reduced dry weight accumulation and decreased reproductive capacity (Rice, 1984). These could be because the allelochemicals are known to alter wide array of physiological reactions such as enzyme activities, cell division and ultrastructure, cell elongation, membrane permeability and ion uptake (Kalinova, 2010).

Cover crop allelopathy can be optimized depending on the production and release of allelochemicals from the cover crops and susceptibility of the receptor plant (Kalinova, 2010). External environmental conditions, development stages of the cover crops, plants tissues and the genetic composition of the cover crop can influence the production and active release of allelochemicals from the donor plant (Batish *et al*., 2001; Peng *et al*., 2004). Regarding the receptor plant, inhibitory effects are influenced by biotic and abiotic stress factors, the quantity of allelochemicals, genetic makeup, seed size and depth of sowing and ability of the receptor plant, in this case the weed, to detoxify the allelochemicals (Kalinova, 2010). For instance allelopathic inhibitory effects are higher when there are stress factors such as water deficit, high temperature, high irradiance when the plant is damaged by pathogen, insects and herbivores, or faced nutrient deficiency (Hura *et al*., 2006). Allelopathic effect on the other hand can be negatively influenced by rainfall (Luo, 2005) and vary also with photoperiod (Peng *et al*., 2004). Furthermore, allelochemicals in the

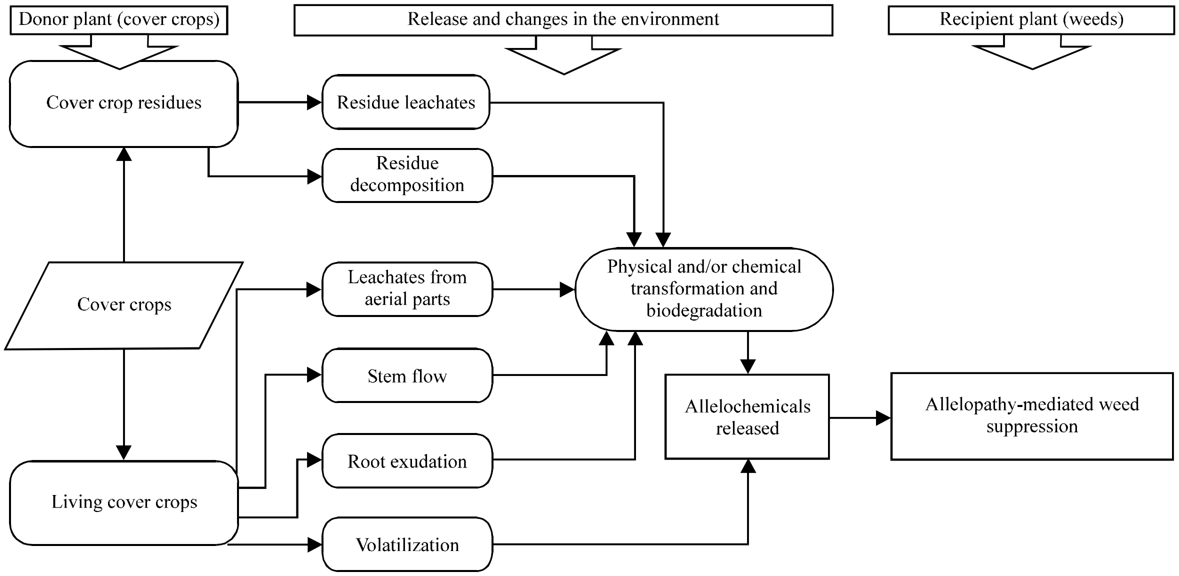

Fig. 3: Method of allelochemical release from cover crops

soil could be adsorbed by soil particles, decomposed by microorganisms and move with running water (Kalinova, 2010), all reducing their quantity and activity.

CONCLUSION

Besides many other agro ecosystem services cover crops help to suppress weeds in different mechanisms. They are employed to suppress weeds either in the form of living plants or as a left on the soil surface or incorporated residues. Living cover crops suppress the development of weed populations through niche pre-emption and cover crop residues suppress or retard weed emergence and growth due to both allelopathic and physical effects. Compared to the straightforward use herbicides, the use of cover crops could serve as ecological weed management.

REFERENCES

Akobundu, I.O., U.E. Udensi and D. Chikoye, 2000. Velvetbean (*Mucuna* spp.) suppresses speargrass (*Imperata cylindrica* (L.) raeuschel) and increases maize yield. Int. J. Pest Manage., 46: 103-108.

Ali, D., A. Ahmad and N. Mohsen, 2014. Determination of allelopathic effect of purple nutsedge (*Cyperus rotundus* L.) on germination and initial development of tomato (*Lycopersicum esculentum*). Indian J. Fundam. Applied Life Sci., 4: 576-580.

Bastiaans, L., D.L. Zhao, N. den Hollander, D.T. Baumann, M. Kruidhof and M.J. Kropff, 2007. Exploiting Diversity to Manage Weeds in Agro-Ecosystems. In: Scale and Complexity in Plant Systems Research: Gene-Plant-Crop Relations, Spiertz, J.H.J., P.C. Struik and H.H. van Laar (Eds.). Springer, New York, pp: 267-284.

Bastiaans, L., R. Paolini and D.T. Baumann, 2008. Focus on ecological weed management: What is hindering adoption? Weed Res., 48: 481-491.

Batish, D.R., H.P. Singh, R.K. Kohli and S. Kaur, 2001. Crop Allelopathy and its Role in Ecological Agriculture. In: Allelopathy in Agroecosystems, Kohli, R.K., P.S. Harminder and D.R. Batish (Eds.). Food Products Press, New York, pp: 121-162.

Blackshaw, R.E., J.R. Moyer, R.C. Doram and A.L. Boswell, 2001. Yellow sweetclover, green manure and its residues effectively suppress weeds during fallow. Weed Sci., 49: 406-413.

Bond, W. and A.C. Grundy, 2001. Non-chemical weed management in organic farming systems. Weed Res., 41: 383-405.

Brainard, D.C. and R.R. Bellinder, 2004. Weed suppression in a broccoli-winter rye intercropping system. Weed Sci., 52: 281-290.

Brennan, E.B. and R.F. Smith, 2009. Winter cover crop growth and weed suppression on the central coast of California. Weed Technol., 19: 1017-1024.

Buhler, D.D., 1996. Development of alternative weed management strategies. J. Prod. Agric., 9: 501-504.

Cheng, H.H., 1992. A Conceptual Framework for Assessing Allelochemicals in the Soil Environment. In: Allelopathy: Basic and Applied Aspects, Rizvi, S.J.H. and V. Rizvi (Eds.)., Chapman and Hall, London, pp: 21-29.

Creamer, N.G. and K.R. Baldwin, 2000. An evaluation of summer cover crops for use in vegetable production systems in North Carolina. HortScience, 35: 600-603.

Crutchfield, D.A., G.A. Wicks and O.C. Burnside, 1986. Effect of winter wheat (*Triticum aestivum*) straw mulch level on weed control. Weed Sci., 34: 110-114.

Dabney, S.M., J.D. Schreiber, C.S. Rothrock and J.R. Johnson, 1996. Cover crops affect sorghum seedling growth. Agron. J., 88: 961-970.

Davis, A.S. and M. Liebman, 2003. Cropping system effects on giant foxtail (*Setaria faberi*) demography: I. Green manure and tillage timing. Weed Sci., 51: 919-929.

Den Hollander, N.G., L. Bastiaans and M.J. Kropff, 2007. Clover as a cover crop for weed suppression in an intercropping design: I. Characteristics of several clover species. Eur. J. Agron., 26: 92-103.

Didon, U.M.E., A.K. Kolseth, D. Widmark and P. Persson, 2014. Cover crop residues-effects on germination and early growth of annual weeds. Weed Sci., 62: 294-302.

Favero, C., I. Jucksch, R.C. Alvarenga and L.M.D. Costa, 2001. Modifications in the population of spontaneous plants in the presence of green manure. Pesquisa Agropecuaria Brasileira, 36: 1355-1362.

Fujii, Y., 2003. Allelopathy in the natural and agricultural ecosystems and isolation of potent allelochemicals from Velvet bean (*Mucuna pruriens*) and Hairy vetch (*Vicia villosa*). Biol. Sci. Space, 17: 6-13.

Gallagher, R.S., E.C.M. Fernandes and E.L. McCallie, 1999. Weed management through short-term improved fallows in tropical agroecosystems. Agrofor. Syst., 47: 197-221.

Gallandt, E.R., M. Liebmanm and D.R. Huggins, 1999. Improving Soil Quality: Implications for Weed Management. In: Expanding the Context of Weed Management, Buhler, D. (Ed.). Taylor and Francis, New York, USA., pp: 95-121.

Gallandt, E.R., T. Molloy, R.P. Lynch and F.A. Drummond, 2005. Effect of cover-cropping systems on invertebrate seed predation. Weed Sci., 53: 69-76.

Grimmer, O.P. and J.B. Masiunas, 2004. Evaluation of winter-killed cover crops preceding snap pea. HortTechnology, 14: 349-355.

Haramoto, E.R. and E.R. Gallandt, 2005. Brassica cover cropping: II. Effects on growth and interference of green bean (*Phaseolus vulgaris*) and redroot pigweed (*Amaranthus retroflexus*). Weed Sci., 53: 702-708.

Hassannejad, S. and A.R. Mobli, 2014. Effects of some cover crops on light extinction and weed coverage in sunflower field. Cercetari Agron. Moldova, 47: 29-40.

Hura, T., S. Grzesiak, K. Hura, M. Grzesiak and A. Rzepka, 2006. Differences in the physiological state between triticale and maize plants during drought stress and followed rehydration expressed by the leaf gas exchange and spectrofluorimetric methods. Acta Physiologiae Plantarum, 28: 433-443.

Jordan, N., J. Zhang and S. Huerd, 2000. Arbuscular-mycorrhizal fungi: Potential roles in weed management. Weed Res., 40: 397-410.

Kalinova, J., 2010. Allelopathy and Organic Farming. In: Sociology, Organic Farming, Climate Change and Soil Science, Lichtfouse, E. (Ed.). Vol. 3, Springer Science and Business Media, New York, pp: 379-418.

Kruidhof, H.M., L. Bastiaans and M.J. Kropff, 2008. Ecological weed management by cover cropping: Effects on weed growth in autumn and weed establishment in spring. Weed Res., 48: 492-502.

Kruidhof, H.M., L. Bastiaans and M.J. Kropff, 2009. Cover crop residue management for optimizing weed control. Plant Soil, 318: 169-184.

Kumar, S., K. Habib and T. Fatma, 2008. Endosulfan induced biochemical changes in nitrogen-fixing cyanobacteria. Sci. Total Environ., 403: 130-138.

Liebman, M. and A.S. Davis, 2000. Integration of soil, crop and weed management in low-external-input farming systems. Weed Res., 40: 27-47.

Liebman, M. and C.L. Mohler, 2001. Weeds and the Soil Environment. In: Ecological Management of Agricultural Weeds, Liebman, M., C.L. Mohler and C.P. Staver (Eds.). Cambridge University Press, Cambridge, UK., pp: 210-268.

Linares, J., J. Scholberg, K. Boote, C.A. Chase, J.J. Ferguson and R. McSorley, 2008. Use of the cover crop weed index to evaluate weed suppression by cover crops in organic citrus orchards. HortScience, 43: 27-34.

Luo, S.M., 2005. Allelopathy in South China agroecosystems. Proceedings of the 4th World Congress on Allelopathy, August 21-26, 2005, Charles Sturt University, Wagga Wagga, NSW., Australia, pp: 144-153.

Manici, L.M., F. Caputo and V. Babini, 2004. Effect of green manure on *Pythium* spp. population and microbial communities in intensive cropping systems. Plant Soil, 263: 133-142.

Matthiessen, J.N. and J.A. Kirkegaard, 2006. Biofumigation and enhanced biodegradation: Opportunity and challenge in soilborne pest and disease management. Crit. Rev. Plant Sci., 25: 235-265.

Moonen, A.C. and P. Barberi, 2006. An ecological approach to study the physical and chemical effects of rye cover crop residues on *Amaranthus retroflexus*, *Echinochloa crus-galli* and maize. Ann. Applied Biol., 148: 73-89.

Morvillo, C.M., E.B. de la Fuente, A. Gil, M.A. Martinez-Chersa and J.I. Gonzalez-Andujar, 2011. Competitive and allelopathic interference between soybean crop and annual wormwood (*Artemisia annua* L.) under field conditions. Eur. J. Agron., 34: 211-221.

Ngouajio, M. and H. Mennan, 2005. Weed populations and pickling cucumber (*Cucumis sativus*) yield under summer and winter cover crop systems. Crop Prot., 24: 521-526.

Ngouajio, M. and M.E. McGiffen, 2002. Going organic changes weed population dynamics. HortTechnology, 12: 590-596.

Oerke, E.C., 2006. Crop losses to pests. J. Agric. Sci., 144: 31-43.

Ohno, T., K. Doolan, L.M. Zibilske, M. Liebman, E.R. Gallandt and C. Berube, 2000. Phytotoxic effects of red clover amended soils on wild mustard seedling growth. Agric. Ecosyst. Environ., 78: 187-192.

Peachey, R.E., R.D. William and C. Mallory-Smith, 2004. Effect of no-till or conventional planting and cover crops residues on weed emergence in vegetable row crop. Weed Technol., 18: 1023-1030.

Peng, S.L., J. Wen and Q.F. Guo, 2004. Mechanism and active variety of allelochemical. Acta Botanica Sinica, 46: 757-766.

Reberg-Horton, S.C., J.D. Burton, D.A. Danehower, G. Ma and D.W. Monks *et al*., 2005. Changes over time in the allelochemical content of ten cultivars of rye (*Secale cereal* L.). J. Chem. Ecol., 31: 179-193.

Reddy, K.N. and C.H. Koger, 2004. Live and killed hairy vetch cover crop effects on weeds and yield in glyphosate-resistant corn. Weed Technol., 18: 835-840.

Rice, E.L., 1984. Allelopathy. 2nd Edn., Academic Press, London, UK.

Samedani, B., A.S. Juraimi, S.A.S. Abdullah, M.Y. Rafii, A.A. Rahim and M.P. Anwar, 2014. Effect of cover crops on weed community and oil palm yield. Int. J. Agric. Biol., 16: 23-31.

Sarrantonio, M. and E. Gallandt, 2003. The role of cover crops in North American cropping systems. J. Crop Prod., 8: 53-74.

Sullivan, P., 2003. Overview of cover crops and green manures. ATTRA-National Sustainable Agricultural Information Service, Fayetteville, USA. http://www.moissonquebec.com/documents/cover-crops.pdf

Teasdale, J.R., C.E. Beste and W.E. Potts, 1991. Response of weeds to tillage and cover crop residues. Weed Sci., 39: 195-199.

Teasdale, J.R. and C.L. Mohler, 1993a. Light transmittance, soil temperature and soil moisture under residue of hairy vetch and rye. Agron. J., 85: 673-680.

Teasdale, J.R. and C.S. Daughtry, 1993b. Weed suppression by live and desiccated hairy vetch (*Vicia villosa*). Weed Sci., 41: 207-212.

Teasdale, J.R., 2003. Principles and Practices for Using Cover Crops in Weed Management Systems. In: Weed Management for Developing Countries: Addendum 1, Labrada, R. (Ed.). Chapter 3.1, Food and Agriculture Organization of the United Nations, Rome, Italy, ISBN-13: 9789251050194, pp: 169-178.

Teasdale, J.R., R.W. Mangum, J. Radhakrishnan and M.A. Cavigelli, 2004. Weed seedbank dynamics in three organic farming crop rotations. Agron. J., 96: 1429-1435.

Teasdale, J.R. and C.I. Mohler, 2005a. The quantitative relationship between weed emergence and the physical properties of mulches. Weed Sci., 48: 385-392.

Teasdale, J.R. and P. Pillai, 2005b. Contribution of ammonium to stimulation of smooth pigweed (*Amaranthus hybridus* L.) germination by extracts of hairy vetch (*Vicia villosa* Roth) Weed Biol. Manage., 5: 19-25.

Teasdale, J.R., C.B. Coffman and R.W. Mangum, 2007. Potential long-term benefits of no-tillage and organic cropping systems for grain production and soil improvement. Agron. J, 99: 1297-1305.

Wright, G.C., W.B. McCloskey and K.C. Taylor, 2003. Managing orchard floor vegetation in flood-irrigated citrus groves. HortTechnology, 13: 668-677.

Yenish, J.P., A.D. Worsham and W.S. Chilton, 1995. Disappearance of DIBOA-glucoside, DIBOA and BOA from rye (*Secale cereal* L.) cover crop residue. Weed Sci., 43: 18-20.