Interaction of rapeseed (Brassica naphus L) residue management and smother crops for weed control in corn (Zea mays L.) and soybean [Glycine max (L) Merr]

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Interaction of rapeseed (Brassica naphus L.) residue management and smother crops for weed control in corn (Zea mays L.) and soybean [Glycine max (L.) Merr.]

by

Juan Lorenzo Medina Pitalua

A dissertation submitted to the graduate faculty in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Crop Production and Physiology

Major Professors: Micheal D. K. Owen and Douglas D. Buhler

Iowa State University

Ames, Iowa

1999
This is to certify that the doctoral dissertation of

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For the Major Program

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For the Graduate College
DEDICATION

To Esperanza and my sons Osmar, Jair, Amauri, for their support and love. To my parents, brothers and sisters for believing in me. To Paulo Nogueira de Camargo my friend, for his guidance in my professional career. To God for holding and providing me the strength necessary to achieve my goals.
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GENERAL INTRODUCTION

Weeds are one of the most important and consistent factors in agriculture systems and cause severe reductions in crop productivity (Zimdahl 1980). Soil disturbance in conventional tillage crop systems has influenced weeds to develop effective adaptive mechanisms. These mechanisms include seed dormancy and prolific seed production (Harper 1977; Rice 1979). The lack of soil movement in no tillage and minimum tillage systems changes the weed seed distribution pattern in the soil. These changes interact with physical and potential allelopathic properties of plant residues on the soil surface, affecting the dormancy and germination mechanisms by altering light, temperature, moisture patterns, and the chemical environment (Almeida 1981).

Traditional weed management has concentrated on tillage and chemical weed control. Soil erosion and water contamination with herbicides, as the results of the long-term application of these techniques, have social, economic, and ecological costs (Wyse 1994). A new vision for agriculture, "Sustainable Agriculture", is attempting to find ways to use less tillage, pesticides, and synthetic fertilizers. At this time, systems have been developed that allow for considerable reductions in tillage and fertilizer rates; however, the dependency on herbicides to control weeds continues (Wyse 1994). Producers have few viable options for control of weeds due in part to the wide genetic diversity that confers weeds with a strong adaptive ability to compete and survive.

One alternative to avoid or reduce the intensive use of herbicides in agriculture could be the use of cover crops that suppress weed growth. Cover crops may provide an alternative method of weed control, without herbicide use, while reducing erosion and improving soil

Lal et al. (1991) and Wyse (1994) concluded that lack of winter hardiness was a serious constraint to the potential use of fall-seeded cover crops in the North Central region of the United States. Others limitations of fall-seeded cover crops are spring soil moisture depletion, and in some cases, the need for herbicides to eliminate the cover crops (Buhler and Kohler 1994). Preliminary research in central Iowa and Minnesota indicated better success for spring-seeded cover crops as a weed control system (Buhler and Kohler 1994; De Haan 1994; Lal et al. 1991). Spring smother crops do not need to be winter hardy and may eliminate the need for herbicide use (De Haan et al. 1994).

The establishment of a cover crop early in the spring could reduce the natural weed infestation prior to the establishment of corn (Zea mays L.) and soybean [Glycine max (L.) Merr.]. Additionally, the residues produced by cover crops could continue to suppress weeds by physical and allelopathic characteristics after crop establishment.

Thus, the objectives of this research were to: a) study the feasibility of rapeseed (Brassica naphus L.) as a cover crop early in the spring; b) determine the effect of rapeseed residue treatments on weed population dynamics; and c) compare berseem clover (Trifolium alexandrinum L.) and sava medic (Medicago scutellata L.) as smother crops with other weed control practices in soybean and corn.

**Dissertation Organization**

This dissertation is divided into five chapters. The first two chapters are a general introduction and a literature review. The third and fourth chapters are two papers that have been prepared for submission to the Weed Science Journal. The papers describe the viability
of rapeseed as a cover crop and the effect of other weed control practices in soybeans (first paper) and corn (second paper). In the last chapter, general conclusions are presented summarizing the important aspects of this research. The appendix presents a related report of growth chamber work conducted in 1998, testing the effect of temperature and seed treatments on the germination and establishment of rapeseed. Literature cited in the different chapters of this dissertation is listed at the end followed by general acknowledgments.

The main theme of this research was to evaluate the use of rapeseed and non-conventional options such as smother crops for weed control. The effects of herbicide application and cultivation were also included in soybean and corn experiments in 1997.
LITERATURE REVIEW

Definition of Concepts

Two concepts, sustainable agriculture and cover crops, are very important to this research and must be defined before they are used in this dissertation. Many definitions have been proposed and it is important to understand how these concepts are portrayed in this work.

Sustainable Agriculture

According to the 1990 Food, Agriculture, Conservation, and Trade Act, sustainable agriculture is defined as an integrated system of plant and animal production practices having a site-specific application that will, over the long term: a) satisfy human food and fiber needs; b) enhance environmental quality and the natural resource base upon which the agriculture economy depends; c) make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls; d) sustain the economic viability of the farm operation; and e) enhance the quality of life for farmers and society as a whole (Anonymous 1990). Wyse (1994) defined sustainable agriculture as a system that aims to incorporate the long term maintenance of the natural resources and agriculture productivity with minimal adverse environmental impacts, adequate economic returns to farmers, and the fulfillment of social needs of farm families and communities.

An agronomic definition proposed by Wright (1994) describes sustainable agriculture as "a farming system involving some changes in field operations, such as: 1) reduced inputs of fertilizer, particularly nitrogen; 2) reduced inputs of chemicals used to control the growth of weeds; 3) the addition of oats (Avena sativa L.) and legumes to row crop rotations of corn (Zea mays L) and soybean [Glycine max (L.) Merr.] to improve soil health, soil tilth,
and structure; 4) planting crops in strips on rolling and gently rolling land following the contour of the land or planting across the slope to save soil from the erosion; and 5) planting cover crops in the fall to cover soybean stubble during winter, control erosion, and inhibit weed growth in spring”. There are other, simpler definitions that consider sustainable agriculture as the optimum system that requires minimum or no tillage of the soil. However, it does not matter how complex these definitions are, sustainable agriculture focuses on a stable system that requires minimum external inputs in order to maintain the benefits of profit, food, social stability, and environmental quality.

**Cover Crops**

Cover crops are defined as “legumes, cereals, or an appropriate mixture grown specifically to protect the soil against erosion, ameliorate soil structure, enhance soil fertility, and suppress pests, including weeds, insects, and pathogens” (Hardwick 1981). Cover crops are specifically planted to fill gaps in either time or space when cash crops leave the ground bare. Cover crops do not necessarily have to be for harvest.

There are basically two ways to use cover crops for weed control. The most common is referred to as “killed cover crops”, “dead mulch”, or “mulch” where the cover crops are established in the fall and provide a dense ground cover by early spring, thus suppressing weed germination and establishment. Cover crops grow during the fall season, and before maturation in the spring are killed by mowing, tillage, or herbicides. The resultant residue or mulch provides an excellent seed bed for row crops. When the climate is not restrictive, it is possible to obtain grain from the cover crops, and after harvest, the straw remains on the soil providing a thick mulch that permits row crop establishment and weed control.
A second way of using a cover crop is known as "living mulch" or "smother crop", in which the cover crop is established before, at, or after the crop has been established. The smother crop grows for all or part of the season to compete with weeds and provide soil cover. It is also important that the smother crop does not reduce crop yield. Plant species with a short life cycle, fast establishment, and adequate ground cover to provide weed control and that provide soil protection, and nitrogen are good candidates for a smother crop. In this context, cover crops may play a very important role in sustainable agriculture if they minimize herbicide dependency, improve the performance of crops in no tillage systems, reduce soil erosion, and reduce the necessity of fertilizer application.

**Cover Crops**

Three mechanisms, usually working together, are responsible for the weed control action of cover crops. These include a physical mechanism, a chemical mechanism, and a biotic mechanism.

**Physical mechanism**

Light interception by plant residues imposes an unfavorable condition for the germination of many weed species. Changes in seed response to light during soil cultivation have been reported for different species (Baskin and Baskin 1980; Botto et al. 1998; Buhler 1997). Species for which germination is stimulated by light are: common ragweed (*Ambrosia artemisiifolia* L.), hedge mustard (*Sisymbrium officinale* (L.) Scop.), common lambsquarters (*Chenopodium album* L.), ryegrass (*Lolium multiflorum* Lam.), and many more. Botto et al. (1998) suggested that only the light stimulus perceived by the seeds during soil cultivation was effective in triggering germination. The physical impedance of a thick mulch layer on the emergence of weed seedlings, as well as the modification to the soil
environment (temperature, moisture, and biotic components) are additional physical actions that affect weed community dynamics (Almeida 1981; Barnes and Putnam 1983; Cochran et al. 1977).

**Chemical mechanism**

Living plants and plant residues can release compounds that are toxic to other plants. These substances are known as "phytotoxins", "allelochemicals", or "allelopathic substances" (Guenzi and McCalla 1962; Kimber 1967; Rice 1979). Allelochemicals inhibit or reduce weed seed germination and interfere with seedling and plant development (Almeida 1981; McCalla and Norstadt 1974; Rice 1984). Allelochemicals in living plants may be released by any plant part, however roots are considered the most important organ releasing allelochemicals for weed suppression (Rice 1979). Allelochemicals may be present in unweathered crop residues and/or produced by the decomposition of the residues by microorganisms (Elliot et al. 1980; Patrick 1971).

Doran and Linn (1996) reported that numerous allelochemicals have been isolated and identified from decaying plant residues as products of microbial activity. A variety of water-soluble organic acids, such as phenolic, aromatic, and short-chain fatty acids has been found in crop residues. *Brassica* residues contain glucosinolate substances that can be hydrolyzed in the soil to form different compounds such as isothiocynates (ITC), more commonly known as mustard oils (Evenari 1949; Fenwick et al. 1983, 1989; Horricks 1969; Purvis et al. 1985). Thiocyanates, nitriles, isoprenoids, and benzenoids caused growth suppression and inhibited seed germination in several plant species including weeds and crops (Boydston and Hang 1995; Brown et al. 1991; Chew 1988; Cole 1976).
Allelochemicals from fungi, including patulin, oxalic acid, and other metabolic by-products of microbial fermentation, have demonstrated allelopathic effects on plants.

**Biotic mechanism**

This mechanism is based on the ability of cover crops to compete and because established faster than weeds. Filling sites in the soil early in the growing season and having high rates of growth make cover crops successful for weed control. Plant population is a function of seed density and the frequency of "safe sites" (a zone in which a seed may find the suitable conditions for breaking dormancy, and germination, and the absence of specific hazards such as predators, competitors, pathogens, and toxic soil constituents) (Harper 1977). Therefore cover crops should compete for these safe sites with weeds, starting with faster and earlier establishment to occupy these safe sites (Akobundu 1980).

**Cover Crop Residues**

The desirable characteristic of cover crop residues is the high production of biomass, thus suppressing weeds (Almeida 1981; Worsham 1991). Quantity, distribution, and chemical composition of the residue regulate the weed control action of cover crops (Weston 1996). Rivas and Bauman (1994) found that weeds decreased with increasing amounts of wheat (*Triticum aestivum* L.) straw in no-tillage, double-cropped soybean and edible bean (*Phaseolus* spp.) production. Miller and Jordan (1994) worked with small grain cover crops in no-tillage soybean systems and found that more biomass was produced in fall than spring cover crop plantings. However, both planting times provided weed control comparable to conventional practices.

Warnes et al. (1991) showed up to 90% weed biomass reduction by rye (*Secale cereale* L.) mulch. Rye provided better weed control when planted in fall than spring,
probably because more mulch was produced with the fall planting. There were no significant soybean yield differences between hand-weeded and fall rye treatments. These results and the effects on weed seed germination using rye extracts suggested possible allelopathic effects of rye residue against weed germination and growth (Warnes et al. 1991).

High dry matter production for fall-planted cover crops is commonly achieved in regions with favorable growing conditions. In the North Central region of the United States, establishing cover crops during fall has been difficult. Corak et al. (1991) tried to establish oats during the fall following soybeans in Iowa. They found the frost-free period was too short for oats to produce enough dry matter to protect the soil and control weeds in the spring. Therefore, winter hardiness of the potential cover crop is a requirement (Power and Biederbeck 1991). In Brazil, however, Calegari (1991) showed good oat development in winter resulting in excellent soil protection and weed control in soybeans and corn. Power and Biederbeck (1991) indicated that successful implementation of cover crops had generally occurred in the Southeast region of the United States.

The quality of cover crops refers to their allelopathic properties resulting in inhibited germination or decreased initial growth of weeds and/or crops (Anderson and Cruse 1995). Allelopathic properties depend on the cover crop species and on the environmental and biotic conditions (Einhelling 1996). The production of allelochemicals is favored when cool, wet, dry, or anaerobic conditions are prevalent during cover crop development (Cochran et al. 1977; Lynch 1978, 1987; McCalla et al. 1963). Such conditions are prevalent in the North Central region of the United States, where the fall is typically dry and cool and the early spring is cool and wet. Thus, cover crops established during fall or early spring are expected
to have increased allelochemical production when compared with cover crops planted in favorable growing conditions.

McCalla and Army (1961) showed that crop yield reduction attributable to the accumulation of allelochemicals present in crop residues was greater during cold years than warm years. Krishnan et al. (1993) evaluated the allelopathic properties of *Brassica napus* L., var. Jupiter; *B. hirta* Moench., var. Martigena; and *B. juncea* (L.) Czern. & Coss., var. Greenwave, by incorporating them as a green manure crop in soybean. Weed seed germination was not reduced but the growth of *Kochia [Kochia scoparia* (L.) Schrad], shepherdspurse [*Capsella bursa-pastoris* (L.) Medik], and green foxtail [*Setaria viridis* (L.) Beauv.] were reduced by the green manures. Krishnam et al. (1994) worked with *Brassica* spp. and *Raphanus* spp. as cover crops and reported a 40 to 59% reduction of weed dry matter.

Boydston and Hang (1995) evaluated fall-planted, spring-incorporated rapeseed for weed control in potato (*Solanum tuberosum* L.). Rapeseed residues incorporated into the soil reduced weed density by 85 and 73% and weed biomass by 96 and 50% in 1992 and 1993, respectively. No potato injury attributable to rapeseed residue was observed. Small-seeded weeds and crops may be more susceptible to injury from rapeseed residues than plants regenerating from vegetative propagules such as potato. Tollsten and Bergstrom (1988) showed the phytotoxic effect of benzyl-ITC from white mustard (*B. hirta* L.) residue on velvetleaf (*Abutilon theophrasti* Medicus.) and sorghum [*Sorghum bicolor* (L.) Moench.].

Barnes and Putnam (1983, 1986), Putman and DeFrank (1983), and Worsham (1991) reviewed the literature on allelochemicals and found that the most important cover crop species used in the USA included oat, wheat, barley (*Hordeum vulgare* L.), rye, sorghum,
sudangrass (*Sorghum sudanense* L.), and ryegrass (*Lolium spp.*). Rye and oat have provided the highest weed control compared with other species, indicating greater utility as cover crops.

Worsham (1991) reviewed the cover crop effects of hairy vetch (*Vicia villosa* Roth.), clovers (*Trifolium incarnatum* L.; *T. subterraneum* L.; *T. album* L.), peas (*Pisum spp.*), medics (*Medicago* spp.), sweet clover (*Melilotus* spp.), alfalfa (*Medicago sativa* L.), and crownvetch (*coronilla varia* L.) reported they provided some weed control. Generally a mixture of grasses and legumes gave better weed control, due to better ground cover (Mangan et al. 1995). These results were consistent with research by De Master and Weller (1993) who worked with rye and hairy vetch residues in vegetable production and found weed control comparable with conventional weed control systems. Mwaja and Mausinas (1993) evaluated the same mixture in vegetable production and concluded that reduced tillage systems using rye and hairy vetch residues helped manage weeds without any negative crop effects. Hutchinson and Weller (1994) evaluated interactions between cover crops and the main crop and demonstrated that corn growing in wheat and rye mulches was smaller and had delayed development compared to corn grown in bare soil.

Different physiological processes seem to be affected by the presence of allelopathic substances. The major alteration occurs in the integrity of the plasma membrane which then causes disruptions of respiration, cell division, nutrient absorption, and photosynthesis (Putnam and Duke 1978; Rice 1979, 1984).

**Smother Crops**

Smother crops can grow part of or the whole growing season with the primary crop (Lal et al. 1991). Using smother crops for weed control can be successful only if the smother
crop does not compete excessively with the cash crop for light, moisture, and nutrients. Smother crops should have a short, smothering growth habit to minimize competition with the crop, but still provide complete ground cover to prevent weed emergence (Cardina and Hartwig 1982). Hartwig and Hoffman (1975) showed good corn yields and weed control when crownvetch (*Coronilla varia* L.) was inhibited with herbicides. Unsuppressed living mulch reduced corn yield (Cardina and Hartwig 1982). Ateh and Doll (1993) tested rye as smother crop for weed control in soybean and found that rye could reduce or even replace herbicides in soybean.

Lal et al. (1991) suggested the use of smother crops established during the spring in the Northeastern and North Central regions of the United States but choosing a species with a winter annual life cycle. Cover crop systems using winter annual species planted in the spring may overcome the lack of winter hardiness, having more chances of success in the Midwest region (Lal et al. 1991).

Buhler and Kohler (1994) indicated that in central Iowa, smother crop establishment and weed control were variable. The best smother crop establishment and subsequent weed control were obtained with sava medic and corn planted on April 25 with moist conditions following planting. *Brassica* spp. and sava medic were effective in suppressing both annual grass and broadleaf weeds (Buhler et al. 1996; Squire et al. 1994). Corn growth and yield were reduced when the smother crops grew the entire season. These reductions were greater with *Brassica* spp. than sava medic possibly due to allelopathic properties that increased the interference with the corn.

In Minnesota, DeHaan et al. (1994) evaluated the effect of a short life cycle, spring-seeded yellow mustard (*Brassica hirta* Moench.) variety on corn development and weed
control. Results indicated that yellow mustard seeded at 2120 seeds/m² with an interference duration of 4 weeks caused a 66% reduction of weed dry weight and a 17% corn yield loss.

In Costa Rica, Nigeria, Taiwan, and Mexico, cover crop research using legumes and grasses has been conducted on perennial plantation and annual crops (Akobundu 1980; Almeida 1981). Wild peanut (*Arachys pintoi* Krapovickas & Gregory nomen nudum.) has been successful as an understory cover crop in Pejibaye (*Bactris gasipaes* H.B.K.) and in other orchards in Costa Rica (Dominguez 1992). Excellent weed control has been obtained with velvetbean (*Stizolobium deeringianum* Bort.) and wild soybean (*Glycine wightii* (Wight & Arnott.) Verdc.) in citrus orchards in Mexico (Dominguez 1992).

In summary, research has demonstrated that cover crops and smother crops are options for weed control in different agricultural systems. The majority of the research has focused on fall seeded winter rye, oat, ryegrass, vetches, clovers, medics, alfalfa, and winter rapeseed (Wyse, 1994). Adaptation of cover crop cultivars to the specific climatic conditions, adequate management of the cover crops, and continued improvement of allelopathic characteristics should be the subjects of future research.
INTERACTION OF RAPESEED (*BRASSICA NAPHS*) RESIDUE
MANAGEMENT WITH SMOTHER CROPS AND OTHER WEED
CONTROL PRACTICES IN SOYBEAN (*GLYCINE MAX*)

A paper to be submitted to Weed Science

Juan L. Medina, Micheal D.K. Owen, and Douglas D. Buhler

Abstract

A series of experiments was conducted at the Agronomy and Agricultural Engineering Research Center near Boone, Iowa during 1996 and 1997. The objectives were to: a) determine the feasibility of rapeseed establishment early in the spring; b) determine the effect of rapeseed management on weed population dynamics; and c) compare the smothering action of sava medic and berseem clover with conventional weed control practices. Rapeseed reduced the density and growth of weeds, smother crops, and soybean, particularly when the residue was left on the soil surface. Rapeseed residue and weed control practices such as herbicides and cultivation affected soybean yield positively through weed control and negatively by the interference on crop growth and smother crops. Based on the results, an effective alternative weed control system for soybean may include rapeseed established early in the spring and the vegetative growth incorporated into the soil, supplemented by berseem clover planted as a smother crop with soybean. These should be followed by a post herbicide application. More research on cover crop establishment, particularly defining the environmental conditions, is needed in the Midwest.

Key words: Berseem clover, cover crops, integrated weed management, residue management, sava medic, spring smother crops.

Introduction

Traditional weed management has concentrated on control by tillage and herbicides. Soil erosion and water contamination are negative consequences of these techniques and have social, economic, and ecological costs (Wyse 1994). At this time, systems have been developed that allow considerable reductions in tillage and fertilizers, however the dependency on herbicides for weed control continues. Producers have few viable options to control weeds, in part due to the genetic diversity that confers weeds with a strong adaptive ability to compete and survive.

Cover crops are legumes, cereals, or other plant species used as an alternative method of weed control while reducing erosion and improving soil quality (Buhler et al. 1996; Hardwick 1981; Lal et al. 1991). Three interactive mechanisms are responsible for the weed control action of cover crops. Cover crops form a physical barrier to light interception and this imposes an unfavorable environment for weed seed germination. Changes in seed response to light during soil cultivation have also been reported for different species by several authors (Baskin and Baskin 1980; Botto et al. 1998; Buhler 1997).

Cover crops also deter weeds by a chemical mechanism where the living cover crop and vegetative residues release toxic compounds. These substances interfere with different physiological processes inhibiting weed seed germination and seedling development (Kimber
Brassica species contain glucosinolate substances that hydrolyze in the soil to form isothiocyanates, thiocyanates, nitriles, isoprenoids, and benzenoids, causing growth suppression and inhibition of seed germination in weeds and crops (Boydston and Hang 1995; Brown et al. 1991; Tollsten and Bergstrom 1988). Cover crops also affect weed populations by a biotic mechanism based on the ability of cover crops to become established and compete with weeds occupying many of the "safe sites" available for seed germination (Harper 1977).

Corak et al. (1991) concluded that the use of fall-seeded cover crops in the North Central region of the United States was constrained by their lack of winter hardiness. Additional limitations of fall-seeded cover crops included soil moisture depletion in the spring and the need for herbicides for their elimination in the spring (Buhler and Kohler 1994). Preliminary research in central Iowa and Minnesota indicated that there was better success using spring-seeded smother crops such as sava medic, berseem clover, and others as a weed control system (Buhler and Kohler 1994; De Haan 1994; Lal et al. 1991).

Spring seeded smother crops do not need to be winter hardy, do not consume soil moisture before crop planting, and may reduce herbicide use when compared with fall smother crops (De Haan et al. 1994). Williams et al. (1998) suggested that smother crops are not widely used for weed control because as a stand-alone tactic, they do not effectively suppress all weeds and their period of action is too short. Therefore, they suggested enhancing cover crop weed control with supplemental postemergence herbicides and inter-row cultivation.

The establishment of a cover crop early in the spring could reduce the weed infestations before or during the establishment of soybean. Additionally, cover crop residues
could continue to suppress weeds later in the growing season through physical and
allelopathic mechanisms. Smother crops living with the crop during a finite time of the
growing season, combined with the complementary action of herbicides and cultivation,
could provide an integrated strategy for weed control.

Thus, the objectives of this research were to: a) study the feasibility of rapeseed
establishment as a cover crop early in the spring; b) determine the effect of rapeseed residue
management on weed population dynamics; and c) compare berseem clover and sava medic
as smother plants with other weed control practices such as herbicides and cultivation.

**Materials and Methods**

Experiments were conducted at the Agronomy and Agricultural Engineering
Research Center of Iowa State University in Boone County, Iowa on a Nicollet loam (Fine-
loamy, mixed mesic, Aquic Hapludolls) and on a Clarion loam (Fine-loamy, mixed, mesic
Typic Hapludolls) soils during 1996 and 1997, respectively.

**Rapeseed Establishment**

Rapeseed (cultivar ‘Dwarf Essex’) was seeded at 6 kg ha⁻¹ (140 seeds m⁻²) on April 5,
1996 and April 10, 1997. Corn was grown the previous year and fields were chisel plowed
the previous fall and received two passes of a harrow disc in the spring. Rapeseed was
planted using a Gandy (1012T) planter, and the seeds were incorporated into the soil with a
rotary hoe in 1996 and a culti-packer in 1997. Poor rapeseed emergence necessitated re-
seeding on April 24, 1996 and April 22, 1997 at the same seeding rate without additional
tillage. Rapeseed plots were 21.6 m by 11.25 m and 22.5 m by 15 m and no-rapeseed plots
were 21.6 m by 3.75 m and 15 m by 7.5 m in 1996 and 1997, respectively. Rapeseed
density, total weed density, and weed density by species were evaluated from six and four
randomly located 0.1 m$^2$ samples per plot on June 1, 1996 and May 31, 1997, respectively. Fresh and dry weights of rapeseed and weeds were evaluated on June 5, 1996 from six randomly located 0.1 m$^2$ samples per plot. Data were analyzed as a complete randomized block design with two treatments (with rapeseed and without rapeseed) and four replications.

**Rapeseed Residue Treatments**

Rapeseed growth was treated immediately before soybean planting on June 5, 1996 and June 6, 1997. Rapeseed residue treatments included: 1) rapeseed cut and residue left on the surface, 2) rapeseed residue incorporated 10 to 12 cm into the soil by using two passes of a disc harrow, 3) rapeseed slot incorporated in a 25 cm wide band over the row at planting using a narrow cultivator attached to the planter, and 4) no rapeseed residue. The slot treatment was eliminated in 1997 due to the strong interference on soybean in 1996.

**Soybean Establishment**

Soybean 'Stine 2250' was planted on June 5, 1996 and June 6, 1997 on the rapeseed residue treatments described above. Planting was conducted using a John Deere no-till planter with five planting units spaced 0.75 m apart and adjusted 5 cm deep, with a seeding rate of 432250 seeds ha$^{-1}$.

Four rapeseed residue treatments and four weed control treatments resulted in 16 treatments for 1996. Three rapeseed residue treatments and the six weed control treatments resulted in 18 treatments for 1997.

**Weed Control Treatments**

After soybeans were established, four and six weed control treatments in 1996 and 1997, respectively, were applied within each rapeseed residue treatment.
Weed control treatments for 1996. Berseem clover and sava medic treatments were planted two days after soybean planting, using an experimental planter dropping 200 seeds per linear meter, and positioning the seeds approximately 7.5 cm on both sides of the soybean row and incorporating them 2.5 to 3.5 cm deep. A weedy check, where weeds grew the entire season with soybean, and a hand weeded check with weeds controlled weekly were included.

Weed control treatments for 1997. Berseem clover was planted on June 6, 1997 using an experimental planter, dropping 200 seeds m\(^{-2}\), positioning the seeds in a 25 cm wide band over the crop row and incorporating with a rake followed by inter-row cultivation 18 days after planting (DAP). A second berseem clover treatment was seeded broadcast between the soybean rows. A split post-emergence combination of sethoxydim (2-[1-(ethoxyimino)butyl]-5-[2-ethylthio]propyl]-3-hydroxy-2-cyclohexen-1-one) plus thifensulfuron (3-[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid) at 0.2 kg a.i ha\(^{-1}\) and 4.3 g a.i ha\(^{-1}\), respectively, were applied as a band between the crop rows as the chemical weed control treatment. The herbicides were applied using a backpack sprayer with Tee Jet 11001E nozzles covering a 50 cm band between the crop rows and calibrated at 187 L ha\(^{-1}\). Sethoxydim was applied 15 days after soybean emergence and thifensulfuron was applied two days later. Inter-row cultivation treatment was applied alone 18 DAP. Weedy and hand weeded checks were included.

Experimental Design and Evaluations

Treatments were arranged as split plots in a complete randomized block with four replications, where the rapeseed residue treatments represented the whole plots and the weed
control treatments were the split-plots.

Soybean density was determined by counting the number of plants in 1 m of row and taking two samples from each plot. Soybean height was measured for eight plants selected at random from the two center rows in each plot. Both parameters were determined 25 and 52 DAP in 1996, and 12, 26, and 44 DAP in 1997. Soybean yield was determined 127 DAP in 1996 and 135 DAP in 1997. Three center rows of each plot were machine harvested in 1996, but were hand harvested and seeds removed from plants with a stationary thresher in 1997.

Weed density was determined by sampling six 0.1 m² quadrats per plot 25 and 52 DAP in 1996 and four 0.1 m² quadrats per plot 17 and 31 DAP in 1997. Weed fresh weight measurements were made 60 and 53 DAP in 1996 and 1997, respectively. A third weed density evaluation was conducted 60 and 48 DAP in 1996 and 1997, respectively. Weed fresh weight and the third weed density evaluation were determined by sampling two 0.25 m² quadrats in each plot.

Smother crop densities were determined by sampling three and four 0.1 m² quadrats per plot 25 and 52 DAP in 1996 and 17 and 31 DAP in 1997. Smother crop fresh weight measurements were made 60 and 53 DAP in 1996 and 1997, respectively. A third smother crop density evaluation was made 60 and 48 DAP in 1996 and 1997, respectively. Smother crop fresh weight and the third smother crop density determination were made by sampling two 0.25 m² quadrats per plot.

Statistical Analysis

Data were subjected to ANOVA using a complete randomized block design for data from the rapeseed establishment treatments, a split plot in a complete randomized block design for weed fresh weight, smother crop fresh weight and soybean yield, and a split-split
plot in a complete randomized block design for weeds, smother crops, soybean densities, and soybean heights as repeated measures over time. The means, where appropriate, were separated by Fisher’s protected LSD test at $P = 0.05$ using the appropriate error term based on significant main effects and interactions.

**Results and Discussion**

**Rapeseed Establishment**

In 1996, the rapeseed density was more than 1.4 million plants ha$^{-1}$ and produced 1450 kg ha$^{-1}$ fresh weight at the time of soybean planting (Table 1). Rapeseed density in 1997 was only 20% of the plant population obtained the previous year. The better performance after reseeding in 1996 resulted from the better soil moisture during establishment. In Iowa, temperatures early in April and May usually are cool (5 to 10°C) and there is an average of 84 and 112 mm/month of precipitation, respectively. Considering a ten day period from four days before to five days after the planting date, 30 mm precipitation was received in 1996 compared with 8.8 mm in the same period in 1997. The average temperature in the same time interval was 10°C for both years. Even though moisture may be appropriate for germination, it could be rapidly lost from the soil surface due to soil preparation, seed incorporation, and the drying action of wind, which flows from 6.4 to 16 km per hour in April. Low soil moisture and cold temperature may be limiting factors for cover crop establishment. Therefore, the spring environmental conditions and management practices for cover crop establishment need to be further defined (Buhler et al. 1998).

**Rapeseed Smothering Action on Weeds**

Rapeseed reduced weed density and growth prior to soybean establishment (Table 1). Rapeseed reduced total weed density by 37%, total weed fresh weight by 64%, and total
weed dry weight by 63% in 1996. In 1997, rapeseed reduced weed density by 33%.

Rapeseed reduced common lambsquarters (*Chenopodium album* L.) density by 66% in 1996. In 1997 there was no statistical difference between common lambsquarters populations with and without rapeseed. However common lambsquarters density in rapeseed plots was about 60% less than in no-rapeseed plots. Giant foxtail (*Setaria faberi* Herrm.), *Amaranthus* spp., and Pennsylvania smartweed (*Polygonum pensylvanicum* L.) densities were not affected by rapeseed.

**Rapeseed Residue Management and Weed Control Practices**

Considerable amount of data was collected and the statistical analyses were confounded by 2-way and 3-way interactions. The interpretation of the data was further confounded by changes in treatments and experiment location between 1996 and 1997. As a result, analyses were conducted separately by year and results will presented in that manner. Specific main effects and 2-way interactions that were statistically significant will be discussed by year. A summary of the data analyses is presented in tables 2 and 3 to provide an overview of the research results. There was no consistent response of weeds to rapeseed residue management or the interaction between rapeseed residue management and weed control treatment. There was a significant 3-way interaction of time, rapeseed residue management, and weed control treatments, however this interaction will be presented in a discussion of the main effects. Soybean yield responded consistently to weed control treatments.

1996

**Changes in weed density.** Sava medic and berseem did not affect weed density compared to the weedy check (Table 4). However, Buhler and Kohler (1994) found up to a
90% weed suppression when using yellow mustard (*Brassica hirta* Moench) or sava medic as
smother crops in corn. Similar results were obtained by Krishnam et al. (1993) when they
evaluated the allelopathic effect of three *Brassica* species as green manure. There was a
significant effect of sample time on weed density (Table 5). Total weed species, giant
foxtail, and common lambsquarters populations decreased between the first and second
evaluation period. However, late germination events increased weed density by the third
evaluation.

*Amaranthus* spp. densities were greatest when rapeseed residue was absent or
incorporated in the soil (Figure 1). Lower *Amaranthus* spp. populations were found when
rapeseed residue was left on the soil surface or incorporated only over the row. Rapeseed
regrew when plants were cut and residues left on the soil surface, which further suppressed
weed growth.

Rapeseed density increased with the time, particularly for the weedy check and
berseem clover treatments (Figure 2). Berseem clover had a higher density than sava medic.
However, smother crop densities declined with time. Sheaffer (1989) indicated that the risk
of legume establishment failure was greater than other major crops due to small seed size,
lack of seedling vigor, and vulnerability to moisture deficits since seeds were sown near the
soil surface.

**Changes in Weed Fresh Weight**

Rapeseed residue treatments interacted with weed control practices for giant foxtail,
*Amaranthus* spp., total weed species, and rapeseed fresh weights in 1996 (Figure 3, Table 2).
Rapeseed residues reduced the total fresh weight of weed species, particularly when rapeseed
was left on the soil surface or incorporated over the crop row. The weedy check and the
Smother crop treatments did not affect the total weed fresh weight except when rapeseed was left on the soil surface. Total weed fresh weight obtained with the sava medic treatment was greater than the weedy check when rapeseed was left on the soil (Figure 3). Similar results were reported by Boydston and Hang (1995), Brown et al. (1991), and Buhler et al. (1998). Cover crop residues may suppress seed germination and growth but also stimulatory responses have been found (Harper 1977; Rice 1979). Anderson and Cruse (1995) reported that soybean produced three chloroform-soluble chemicals that stimulated corn seedling growth. Complex interactions of substances released by plants and residues may play an important role in the recruitment and growth of weed seedlings.

Giant foxtail fresh weight was reduced when rapeseed residue was left on the soil surface or incorporated over the crop row and increased when rapeseed was incorporated or absent (Figure 3). Berseem clover reduced giant foxtail fresh weight in the absence of rapeseed residue on the soil, when compared with sava medic. Similar results were reported by Shilling et al. (1995) who indicated that increased weed growth was caused by soil disturbance and increased soil moisture due to the presence of crop residues.

Smother crops without rapeseed increased *Amaranthus* spp. fresh weight when compared with the weedy check (Figure 3). *Amaranthus* spp. fresh weight was reduced by sava medic with rapeseed incorporated compared with berseem clover, or weedy check treatments. *Amaranthus* spp. fresh weight did not vary when rapeseed was left on the surface or was band incorporated, regardless of the weed control treatment used.

Rapeseed fresh weight increased for rapeseed slot incorporated and rapeseed on the soil surface treatments showing the regrowth capability of rapeseed (Figure 3). Berseem clover fresh weight was 2000 kg ha\(^{-1}\) and sava medic 1120 kg ha\(^{-1}\) in the no rapeseed residue
treatment. Sava medic and berseem clover fresh weights were reduced 37 and 25% by rapeseed left on the soil surface and 42 and 46% by rapeseed incorporated treatment, respectively, compared to the no rapeseed treatment (data not shown). These reductions may be attributable, in part, to the allelochemicals present in *Brassica* species (Cole 1976; Horricks 1969; Krishnan et al. 1993, 1994). However, the physical competition of the *Brassica* and the growth of the smother crops must also be considered as significant factors.

**Soybean Growth and Yield**

**Soybean population density.** Soybean population density varied with time of evaluation. The original soybean population of 385700 plants ha⁻¹ was reduced 5% between 25 DAP and 52 DAP. However, residue management and weed control treatments did not affect soybean density (Table 2). Late soybean stand reduction was reported by Tranel (1999) who indicated that a stand loss less than 20% could be compensated by reproductive growth without a loss of yield.

**Soybean height.** Rapeseed residue treatments did not affect soybean height 25 DAP (Table 6). The rapeseed on the soil surface and slot incorporated treatments reduced soybean height compared with rapeseed incorporated and no rapeseed treatments 52 DAP. Soybean height was not reduced by the incorporation of rapeseed suggesting a dilution of possible rapeseed allelochemicals in the soil by the soil disturbance. Soybean height reduction in the slot incorporated treatment was attributable to the intense interference that rapeseed imposed to the crop. These results are consistent with the findings of Boydston and Hang (1995) and Brown et al. (1991).

**Soybean yield.** There was a significant soybean yield reduction when rapeseed was left on the soil surface or slot incorporated compared with the yield obtained for treatments
without rapeseed residue or when it was incorporated in the soil (Table 6). De Haan et al. (1994) and Buhler et al. (1998) reported the same response in corn and soybean when yellow mustard and rapeseed grew for more than four weeks with the crops. The soybean canopy development was delayed by rapeseed compared with the soybean canopy without rapeseed or when rapeseed residue was incorporated in the soil.

Sava medic and berseem clover did not provide sufficient weed control to avoid soybean yield reductions attributable to weed interference (Table 6). Even though the smoother crops showed some smothering action on weeds, supplemental weed control practices were necessary, as indicated by Williams et al. (1994).

1997

Changes in weed density. Total weeds, giant foxtail, and *Amaranthus* spp. densities were lowest with rapeseed residue on the surface, regardless of the evaluation time (Figure 4). The greatest weed densities occurred for rapeseed incorporated and no rapeseed treatments 17 DAP. Total weeds, giant foxtail, and *Amaranthus* spp. densities declined between 17 and 31 DAP for rapeseed incorporated and no rapeseed treatments. Common lambsquarters density showed a significant increase after 17 DAP when rapeseed was incorporated indicating only a short control period for this weed species.

Total weeds and giant foxtail populations were reduced over time when weed control treatments such as cultivation, herbicide, and berseem clover plus cultivation were applied (Figure 5). The herbicide treatment was less efficient in reducing total weed density compared with berseem clover plus cultivation or cultivation alone during the first and second evaluations, but the treatments were equally effective 48 DAP. Thifensulfuron did not control broadleaf species, particularly common lambsquarters and rapeseed. Berseem
clover planted between soybean rows was no different than the weedy check for weed density.

**Smother crop density.** Berseem clover density was affected by the rapeseed residue treatments and densities declined over time (Table 7). Significant reductions of berseem clover population occurred due to rapeseed on the soil surface and cultivation. The rapeseed incorporated treatment without cultivation had the highest berseem clover population. Berseem clover density declined over time, and the reduction was more pronounced with cultivation. Berseem clover had poor establishment in 1997 compared with 1996, probably because the lack of appropriate soil moisture. There was an accumulation of 24 mm of precipitation in a ten day period, starting four days before and five days after the smother crops planting date in 1996 compared with 1 mm in 1997. Inconsistent spring smother crop establishment was reported by Buhler et al. (1998).

**Changes in weed fresh weight.** Herbicide application caused the greatest reduction in total weeds and giant foxtail fresh weight regardless of the rapeseed residue treatments (Figure 6). Total weed fresh weight was lowest when rapeseed residues were left on the surface regardless of weed control treatments. Rapeseed incorporated reduced the fresh weight of total weed and giant foxtail when berseem clover plus cultivation and cultivation alone were applied.

Common lambsquarters had the highest fresh weight when rapeseed residues were left on the surface regardless of the weed control treatment (Figure 6). Smartweed and rapeseed fresh weights were also higher when rapeseed residue was on the surface compared to rapeseed incorporated and no rapeseed treatments (Table 8).
Rapeseed and berseem clover fresh weights were also affected by weed control treatments (Table 9). Rapeseed fresh weight only showed significant differences when compared with the hand weeded treatment. These results affirm the potential problem for rapeseed to become a weed. On the other hand, berseem clover fresh weight was reduced by cultivation. Poor berseem clover establishment limited its smothering action on weeds (Table 9).

**Soybean Growth and Yield**

**Soybean population density.** Soybean density increased over time when rapeseed remained on the soil surface while densities in the other treatments remained stable (Figure 7). The possible allelopathic and mulch effects of rapeseed residues on the soil surface may have delayed soybean emergence.

**Soybean height.** Soybean height was reduced by herbicide application, berseem clover, and weedy check treatments 44 DAP when compared to cultivation, hand weeded check, and berseem clover plus cultivation treatments (Figure 8). Crop injury by herbicide and weed competition may explain these results. Rapeseed residue on the soil surface also reduced soybean height, and these differences were more evident after 26 DAP (Figure 9).

**Soybean yield.** Soybean yield was reduced when rapeseed residue remained on the soil surface compared to rapeseed incorporated and no rapeseed treatments (Figure 10). These data support the idea that allelopathic properties and the physical action of rapeseed residue restricted the productivity of soybean. This response was demonstrated regardless of differences in the total rapeseed biomass.

Weed control treatments based on smother crops, cultivation and herbicides did not result in soybean yields comparable to the hand weeded treatments (Figure 10). There was a
significant soybean yield increase attributable to herbicides when rapeseed residues were incorporated or when no rapeseed was present. Herbicide treatment resulted in a higher soybean yield than cultivation treatments alone or in combination with berseem clover. The reason why the herbicide treatment was more effective than cultivation was based on better giant foxtail control.

General Discussion

Successful early spring establishment of rapeseed as cover crop occurred in 1996 after reseeding, but establishment was poor in 1997. Rapeseed reduced weed density, and biomass and affected the composition of weed community. Sava medic and berseem clover establishment was successful in 1996 due to favorable soil moisture, but based on the better performance of berseem clover in reducing weed density and land limitations, sava was not used in 1997. Favorable weather conditions were not present during 1997, therefore berseem clover was poorly established. The frequency of establishment failures increased with later planting, probably due to increased temperature and soil moisture limitations (Buhler et al. 1998). Spreading seed on the soil surface and using shallow incorporation at crop planting was not an effective method for smother crop establishment in soybean.

Different responses in the weed community occurred due to the action of the rapeseed residues, smother crop, herbicide, and cultivation treatments. In 1996, weed density differences occurred due to rapeseed residue treatments over time. In 1997, rapeseed left on the soil surface and incorporated in the soil treatments reduced weed density. The band herbicide treatment was more effective and consistent than cultivation. *Amaranthus* spp. density was greater when rapeseed was incorporated and in the no rapeseed treatment and densities declined over time. Common lambsquarters density was not affected by rapeseed
treatments but increased over time. Cultivation and herbicide treatments reduced total weed and giant foxtail densities and maintained good control over time. Low berseem clover density was due to environmental conditions and was reduced even more by rapeseed residue effects and cultivation.

Weeds grew better where rapeseed residues were absent or when the residues were incorporated in the soil when compared with rapeseed left on the soil surface. Reduced weed growth and density attributable to rapeseed residues on the soil surface suggests that physical and allelopathic effects exist in rapeseed residues and the absence of soil disturbance for this treatment may affect the weed population dynamics. Smother crops in 1996, particularly berseem clover, demonstrated some weed control. This was evident where rapeseed residue was present. In 1997, the herbicide band treatment reduced weed biomass more effectively than cultivation, which was unable to control weeds within the crop row. Further, cultivation may promote weed germination (Buhler 1995). Neither the smother crops nor cultivation controlled giant foxtail as effectively as the herbicide treatment.

Soybean density was reduced and growth delayed by rapeseed residue left on the soil surface. Soybean height was reduced by rapeseed residue on the soil surface and incorporated in the soil treatments, as well as by the herbicide treatment. Soybean yield reflected the performance of the rapeseed residue and weed control treatments on weeds and crop interference. In 1996, soybean yield was not affected by rapeseed residue treatments. The positive effect of rapeseed residue treatments on weed control was not reflected in soybean yield due to the interference rapeseed imposed on soybean growth. In 1997, crop yield was determined by the effectiveness of the herbicide treatment on giant foxtail.
Cultivation did not control giant foxtail, which continued growing in the soybean row and reduced yield.

**Conclusions**

The research indicated that rapeseed affected weed control when used as cover crop due to a smothering action. Rapeseed residue reduced the density and growth of weeds, smother crops and soybean, particularly when rapeseed residues remained on the soil surface. We believe that complex mechanisms are involved in these responses including residues from the previous crop, the placement of rapeseed residues, and soil disturbance, which interact to affect the dynamics of the weed community. Soybean productivity reflected the performance of the rapeseed residue management and weed control practices.

**Literature Cited**

Londrina, Pr. Brazil.


(Glycine max) cultivar, tillage, and rye (Secale cereale) mulch on sicklepod (Senna


Tranel, D. 1999. Soybean stand reduction during reproductive growth. Seminars in Crop
Production and Physiology. Agronomy Dept. Iowa State University. Ames, IA.
(Abstract).


agriculture systems. Weed Technol. 3:403-407.
Table 1. Rapesced and weed density and fresh weight prior to soybean establishment.

<table>
<thead>
<tr>
<th>Year</th>
<th>Rapeseed Density</th>
<th>Rapeseed Fresh Weight</th>
<th>Rapeseed Dry Weight</th>
<th>Total Weed Density</th>
<th>Total Weed Fresh Weight</th>
<th>Total Weed Dry Weight</th>
<th>Weed density</th>
<th>Common**</th>
<th>Giant foxtail</th>
<th>Amaranthus sp</th>
<th>Pennsylvania smartweed</th>
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<tbody>
<tr>
<td>1996 with rapeseed</td>
<td>1440 a*</td>
<td>1450 a</td>
<td>260 a</td>
<td>5520 a</td>
<td>420 b</td>
<td>100 b</td>
<td>1650 b</td>
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<td>660 a</td>
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<tr>
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<td>0 b</td>
<td>0 b</td>
<td>8720 a</td>
<td>1160 a</td>
<td>270 a</td>
<td>4870 a</td>
<td>2620 a</td>
<td>950 a</td>
<td>220 a</td>
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</tr>
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<td>-</td>
<td>-</td>
<td>12240 b</td>
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<td>3070 a</td>
<td>8960 a</td>
<td>120 a</td>
<td>90 a</td>
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</tr>
<tr>
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<td>0 b</td>
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<td>-</td>
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<td>-</td>
<td>-</td>
<td>7720 a</td>
<td>10210 a</td>
<td>200 a</td>
<td>290 a</td>
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</tr>
</tbody>
</table>

* Values with same letter are not significantly different at the \( P \leq 0.05 \) level. These means are only comparable within same column and within the same year.

** Common lambsquarters (Chenopodium album); Giant foxtail (Setaria faberi); Pennsylvania smartweed (Polygonum pensylvanicum).
Table 2. Summary of the sources of variation from the analyses of variance for weed, rapeseed and smother crop density and fresh weight and crop density, height, and yield in soybean during 1996.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rmi</th>
<th>Wct</th>
<th>Rmi by Wct</th>
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<th>Time by Wct</th>
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<td>NS</td>
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</tr>
<tr>
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*Rmi, rapeseed residue management; Wct, Weed control treatments.

b F-test significant at: * = 0.05, ** = 0.01, NS = not significant at P > 0.05, na = not applicable.
Table 3. Summary of the sources of variation from the analyses of variance for weed, rapeseed, and smother crop density and fresh weight and crop density, height and yield in soybean during 1997.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source</th>
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<th>Wct</th>
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<td>Weed and rapeseed density</td>
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<td>**</td>
<td>NS</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Common lambsquarters</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td><em>Amaranthus</em> spp.</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Pennsylvania smartweed</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>**</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Weed and rapeseed fresh weight</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total weed species</td>
<td>**</td>
<td>**</td>
<td>NS</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giant foxtail</td>
<td>**</td>
<td>**</td>
<td>NS</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common lambsquarters</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Amaranthus</em> spp.</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pennsylvania smartweed</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rapeseed</td>
<td>**</td>
<td>NS</td>
<td>**</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smother crops</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td>*</td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>Fresh weight</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td>NS</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Height</td>
<td>**</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td>**</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Yield</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rrm, rapeseed residue management; Wct, Weed control treatments.

F-test significant at: * = 0.05, ** = 0.01, NS = not significant at P > 0.05, na = not applicable.
Table 4. Effect of smother crops on weed density in soybean, 1996a.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Total weeds</th>
<th>Giant foxtail(^b)</th>
<th>Amaranthus spp.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>plants m(^2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berseem clover(^c)</td>
<td>214</td>
<td>116</td>
<td>43</td>
</tr>
<tr>
<td>Sava medic(^d)</td>
<td>163</td>
<td>68</td>
<td>52</td>
</tr>
<tr>
<td>Weedy</td>
<td>229</td>
<td>120</td>
<td>43</td>
</tr>
<tr>
<td>Hand Weeded</td>
<td>20</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>97</td>
<td>63</td>
<td>33</td>
</tr>
</tbody>
</table>

\(^a\) Means averaged over four rapeseed residue treatments, representing 12 observations.

\(^b\) Giant foxtail (Setaria faberi).

\(^c\) Trifolium alexandrinum L.

\(^d\) Medicago scutellata L.
Table 5. Effect of evaluation time on weed density in soybean, 1996.

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Total weeds</th>
<th>Giant foxtail $^b$</th>
<th>Common lambsquarters</th>
<th>Pennsylvania smartweed</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 DAP $^c$</td>
<td>170</td>
<td>72</td>
<td>34</td>
<td>5</td>
</tr>
<tr>
<td>52 DAP</td>
<td>110</td>
<td>58</td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td>60 DAP</td>
<td>192</td>
<td>106</td>
<td>44</td>
<td>2</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>34</td>
<td>25</td>
<td>10</td>
<td>2</td>
</tr>
</tbody>
</table>

$^a$ Means averaged over four rapeseed residue treatments and four weed control treatments, representing 48 observations.

$^b$ Giant foxtail (*Setaria faberi*); Common lambsquarters (*Chenopodium album*); Pennsylvania smartweed (*Polygonum pensylvanicum*).

$^c$ DAP = Days after planting.
Table 6. Effect of rapeseed (**Brassica naphus** L.) residue treatments and weed control treatments on soybean growth and yield, 1996.

<table>
<thead>
<tr>
<th>Rapeseed treatments(^a)</th>
<th>Height(^b)</th>
<th>Yield (\text{kg ha}^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 DAP cm</td>
<td>52 DAP cm</td>
</tr>
<tr>
<td>On the soil surface</td>
<td>18.4</td>
<td>43.1</td>
</tr>
<tr>
<td>Soil incorporated</td>
<td>17.8</td>
<td>52.3</td>
</tr>
<tr>
<td>Slot incorporated</td>
<td>19.7</td>
<td>41.8</td>
</tr>
<tr>
<td>No rapeseed</td>
<td>18.5</td>
<td>53.6</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>1.7</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weed control treatments (^c)</th>
<th>(^d)</th>
<th>(^e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berseem clover (^d)</td>
<td></td>
<td>2235</td>
</tr>
<tr>
<td>Sava medic (^e)</td>
<td></td>
<td>2467</td>
</tr>
<tr>
<td>Weedy check</td>
<td></td>
<td>2414</td>
</tr>
<tr>
<td>Hand weeded</td>
<td></td>
<td>3490</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td></td>
<td>413</td>
</tr>
</tbody>
</table>

\(^a\) Means for yield represent the average from four replications.

\(^b\) Means averaged over weed control treatments representing 16 observations.

\(^c\) Means averaged over rapeseed residue treatments representing 32 observations.

\(^d\) *Trifolium alexandrinum* L.

\(^e\) *Medicago scutellata* L.

<table>
<thead>
<tr>
<th>Rapeseed treatments&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Be Cl Cu&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Be Cl br&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>On the soil surface</td>
<td>22</td>
<td>30</td>
</tr>
<tr>
<td>Soil incorporated</td>
<td>34</td>
<td>74</td>
</tr>
<tr>
<td>No rapeseed</td>
<td>45</td>
<td>59</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Time of evaluation&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 DAP</td>
<td>58</td>
<td>74</td>
</tr>
<tr>
<td>31 DAP</td>
<td>20</td>
<td>66</td>
</tr>
<tr>
<td>48 DAP</td>
<td>23</td>
<td>24</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td></td>
<td>11</td>
</tr>
</tbody>
</table>

<sup>a</sup> Means averaged over three evaluation times representing 12 observations.

<sup>b</sup> Be Cl Cu = Berseem clover (*Trifolium alexandrinum*) plus cultivation

<sup>c</sup> Be Cl br = Berseem clover between the rows

<sup>d</sup> Means averaged over four rapeseed residue treatments representing 16 observations.
Table 8. Effect of rapeseed (*Brassica naphus*) residue treatment on *P. smartweed* (*Polygonum pensylvanicum*) and rapeseed fresh weight in soybean, 1997.

<table>
<thead>
<tr>
<th>Rapeseed residue treatment</th>
<th>Smartweed kg ha⁻¹</th>
<th>Rapeseed kg ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>On the soil surface</td>
<td>1040 a b</td>
<td>13200 a</td>
</tr>
<tr>
<td>Incorporated</td>
<td>120 b</td>
<td>3520 b</td>
</tr>
<tr>
<td>No rapeseed</td>
<td>40 b</td>
<td>0 b</td>
</tr>
</tbody>
</table>

*a* Means averaged over six weed control treatments, representing 24 observations.

*b* Values with same letter are not significantly different at *P* ≤ 0.05 level.
Table 9. Effect of weed control treatments on rapeseed (*Brassica naphus* L.) and berseem clover (*Trifolium alexandrinum*) fresh weight in soybean, 1997.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rapeseed</th>
<th>Berseem clover</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg ha⁻¹</td>
<td></td>
</tr>
<tr>
<td>Be CI Cuᵇ</td>
<td>7280 aᶜ</td>
<td>27 b</td>
</tr>
<tr>
<td>Be CI brᵈ</td>
<td>7600 a</td>
<td>140 a</td>
</tr>
<tr>
<td>Band herbicides post</td>
<td>7520 a</td>
<td>-</td>
</tr>
<tr>
<td>Cultivation</td>
<td>4400 ab</td>
<td>-</td>
</tr>
<tr>
<td>Weedy check</td>
<td>6560 a</td>
<td>-</td>
</tr>
<tr>
<td>Hand weeded check</td>
<td>0 b</td>
<td>-</td>
</tr>
</tbody>
</table>

Means averaged over three rapeseed residue treatments, representing 12 observations.

ᵇ Be CI Cu = Berseem clover over the row plus cultivation

ᶜ Means within the same column with same letter are not significantly different at \( P \leq 0.05 \) level.

ᵈ Be CI br = Berseem clover broadcast between rows
Figure 1. Effect of rapeseed (*Brassica napus* L.) residue and evaluation time on rapeseed and *Amaranthus* spp. densities in soybean, 1996. *a* Abbreviations: DAP = Days after planting, Rrs = Rapeseed residue on the soil surface, Rri = Rapeseed residue soil incorporated, RrsI = Rapeseed residue slot incorporated, No Rr = No Rapeseed residue. (Means averaged over weed control treatments, each mean represent 16 observations).
Figure 2. Effect of weed control treatments and evaluation time on rapeseed (*Brassica napus* L.) and smother crop densities in soybean, 1996. *DAP* = Days after planting. Berseem clover (*Trifolium alexandrinum* L.), Sava medic (*Medicago scutellata* L.). (Means averaged over rapeseed residue treatments representing 16 observations).
Figure 3. Effect of rapeseed (Brassica naphus L.) residue and weed control treatments on the weed fresh weight in soybean, 1996. *Abbreviations: Rrs = Rapeseed residue on the soil surface, Rri = Rapeseed residue incorporated, RrsI = Rapeseed residue slot incorporated, No Rr = No rapeseed residue. Sava medic (Medicago scutellata L.), Berseem clover (Trifolium alexandrinum L.). (Means averaged from four replications).
Figure 4. Effect of rapeseed (*Brassica naphus* L.) residue treatments and evaluation time on weed density in soybean, 1997. \* Abbreviations: Rrs = Rapeseed residue on the soil surface, Rri = Rapeseed residue soil incorporated, No Rr = No rapeseed residue, DAP = Days after planting. (Means averaged over weed control treatments, representing 24 observations).
Figure 5. Effect of weed control treatments and evaluation time on weed and rapeseed (*Brassica naphus* L.) density in soybean, 1997. * Abbreviations: Be Cl Cu = Berseem clover (*Trifolium alexandrinum* L.) plus cultivations, Be Cl br = Berseem clover between rows, Bd He = Band herbicide postemergence, DAP = Days after planting. (Means averaged over rapeseed residue treatments, representing 12 observations).
Figure 6. Effect of rapeseed (*Brassica naphus* L.) residue treatments and weed control treatments on weed fresh weight in soybean, 1997. * Abbreviations: Be Cl Cu = Berseem clover (*Trifolium alexandrinum* L.) plus cultivation, Be Cl br = Berseem clover between the crop row, Bd He = Band herbicide postemergence; Rrs = Rapeseed residue on the soil surface, Rri = Rapeseed residue incorporated, No Rr = No rapeseed residue. (Means represent four observations).
Figure 7. Effect of rapeseed (*Brassica napus* L.) residue treatments and evaluation time on soybean density, 1997

*Abbreviations: Rrs = Rapeseed residue on the soil surface, Rri = Rapeseed residue incorporated, No Rr = No rapeseed residue, DAP = Days after planting. (Means averaged over weed control treatments, representing 24 observations).
Figure 8. Effect of weed control treatments and evaluation time on soybean height, 1997.

Abbreviations: Be CI Cu = Berseem clover (Trifolium alexandrinum L.) plus cultivation, Be CI br = Berseem clover between the crop row, Bd He = Banded herbicide postemergence, DAP = Days after planting. (Means averaged over rapeseed residue treatments, representing 12 observations.)
Figure 9. Effect of rapeseed (*Brassica napus* L.) residue treatments and evaluation time on soybean height, 1997.

*Abbreviations: Rrs = Rapeseed residue on the soil surface, Rri = Rapeseed residue soil incorporated, No Rr = No rapeseed residue, DAP = Days after planting. (Means averaged over weed control treatments, representing 24 observations).
Figure 10. Effect of rapeseed (*Brassica napus* L.) residue and weed control treatments on soybean yield, 1997.

Abbreviations: Be CI Cu = Berseem clover (*Trifolium alexandrinum* L.) plus cultivation, Be CI br = Berseem clover between the crop row, Bd He = Banded herbicide postmergence; Rrs = Rapeseed residue on the soil surface, Rri = Rapeseed residue soil incorporated, No Rr = No rapeseed residue. (Means averaged from four replications).
INTERACTION OF RAPESEED (BRASSICA NAPHTUS) RESIDUE MANAGEMENT WITH SMOTHER CROPS AND OTHER WEED CONTROL PRACTICES IN CORN (ZEA MAYS)

A paper to be submitted to Weed Science

Juan L. Medina, Micheal D.K. Owen, and Douglas D. Buhler

Abstract

This study investigated rapeseed establishment early in the spring and the effect of rapeseed residue management on weed population dynamics. We also compared the smothering properties of berseem clover and sava medic with traditional weed control practices. Rapeseed residues reduced weed growth up to 76%, but also reduced corn height and yield 42 and 50%, respectively. Reductions were greatest when the residues remained on the soil surface. Rapeseed residues and weed control treatments affected corn yield positively by controlling weeds and negatively by interfering with corn growth. Rapeseed residues incorporated in the soil before corn planting followed by sava medic as smother crop planted with corn and supplemented with a band treatment of nicosulfuron plus atrazine, or cultivation, represent an alternative weed control program for corn. More research on cover crop establishment is needed to define the cultural practices required for consistent cover crop establishment.

Nomenclature: Atrazine, 6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine; nicosulfuron, 2 [[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]-N,N-
dimethyl-3-pyridinecarboxamide; berseem clover, Trifolium alexandrinum L.; rapeseed, Brassica napus L. 'Dwarf essex'; sava medic, Medicago scutellata L.; corn, Zea mays L. 'Pioneer 3563'.

Key Words: Cover crops, crop residues-weed control, integrated weed management, berseem clover, sava medic.

Introduction

Weeds are one of the most important and consistent factors in agricultural systems and cause severe reductions in crop productivity (Zimdahl 1980). One alternative solution to avoid or reduce the intensive use of herbicides in agriculture is the use of cover crops, which have the ability to suppress weed growth (Buhler et al. 1996; Lal et al. 1991).

There are basically two ways to use cover crops for weed control. The most common is referred to as "cover crop residues", known also as "killed cover crops", "dead mulch", "mulch", "crop residues", or "green manure". Cover crops are usually established in the fall and provide a dense ground cover by early spring thus suppressing weed germination and establishment. Cover crops grow during the fall and are killed in the spring before maturation by mowing or with herbicides. The desirable characteristic of this kind of cover crop is high production of biomass, thus suppressing weeds (Almeida 1981; Worsham 1991). Quantity, distribution, and chemical composition of the cover crop residue also affect weed control (Weston 1996). Rivas and Bauman (1994) found that weeds decreased with increasing amounts of wheat (Triticum aestivum L.) straw in no-tillage, double-cropped soybean [Glycine max (L.) Merr.] and edible bean (Phaseolus vulgaris L.) production. Warnes et al. (1991) showed up to a 90% weed biomass reduction by rye (Secale cereale L.) mulch. Boydston and Hang (1995) showed a 96% reduction of weed growth and 85% weed
density reduction due to rapeseed vegetative growth incorporated in the soil when compared with no rapeseed in potato (*Solanum tuberosum* L.) production.

The other option for using cover crops is known as “smother crops”, “living mulch”, or “smother plants”. Smother crops grow all or part of the growing season with the crop, but should have little negative effect on yield (Lal et al. 1991). Smother crops should become established quickly with adequate ground cover to provide weed control and soil protection. Ateh and Doll (1993) tested rye as a smother crop for weed control in soybean and found that rye could reduce or even replace herbicides in the soybean production system.

In the North Central region of the United States, the lack of winter hardiness for some cover crop species planted during the fall resulted in poor and inconsistent establishment and weed control (Buhler et al. 1998; Corak et. al. 1991). Other limitations for fall established cover crops include soil moisture depletion and the need for herbicides for elimination in the spring. Systems using winter annual smother crops, but planted in the spring, may have better chances of success in the Midwest (Lal et al. 1991). *Brassica* spp., sava medic, and berseem clover were effective in suppressing weeds when planted in corn during spring (Buhler et al. 1996).

Spring establishment of rapeseed could reduce weeds before corn establishment. *Brassica* spp. contains glucosinolates that hydrolyze in the soil forming isothiocyanates or mustard oils. These substances suppressed weed growth and inhibited weed seed germination (Boydston and Hang 1995; Brown et al. 1991). Therefore rapeseed residues could suppress weeds by physical and allelopathic characteristics early before corn establishment. Smother crops living with the crop for a finite time with the complementary action of herbicides and cultivation could provide an integrated strategy for weed control.
Thus, the objectives of this research were to: a) study the feasibility of rapeseed establishment early in the spring; b) determine the effect of rapeseed residue on weed population dynamics in a corn production system; and c) compare smoother crops of berseem clover and sava medic with other weed control practices such as herbicides and cultivation.

**Materials and Methods**

Experiments were conducted at the Iowa State University Agronomy and Agricultural Engineering Research Center in Boone County, Iowa, on a Nicollet loam (Fine-loamy, mixed, mesic Aquic Hapludolls) and Spillville loam (Fine-loamy, mixed, mesic Comulic Hapludolls) soils in 1996 and 1997, respectively.

**Rapeseed Establishment**

Rapeseed (cultivar ‘Dwarf Essex’) was seeded at 6.0 kg ha⁻¹ (approximately 140 seeds m⁻²) on April 5, 1996 and April 10, 1997. Soybeans were grown the previous year and fields were chisel plowed the previous fall and conditioned for spring planting by one pass of a harrow disc. Rapeseed was planted using a Gandy (1012T) planter and the seeds were incorporated into the soil using a rotary hoe and a culti-packer in 1996 and 1997, respectively. Poor rapeseed emergence necessitated re-seeding on April 24, 1996 and April 22, 1997, at the same seeding rate without additional tillage. Rapeseed plots were 22.5 by 11.25 m in 1996 and 30 by 7.5 m in 1997. Check plots were 22.5 by 3.75 m and 30 by 7.5 m in 1996 and 1997, respectively. No rapeseed was planted on the check plots. Rapeseed density, total weeds, and weed density by species were evaluated from six and four 0.1 m² samples per plot on June 1, 1996 and May 31, 1997, respectively. Fresh and dry weights of rapeseed and weeds were evaluated only on June 6, 1996 from three 0.1 m² samples per plot, but not in 1997 due to time availability. Data were analyzed as a complete randomized block
design with two treatments (rapeseed and no rapeseed) and three and four replications in 1996 and 1997, respectively.

**Rapeseed Residue Treatments**

Rapeseed residue management treatments were applied on June 10, 1996 and June 5, 1997 before corn planting. In 1996, four rapeseed residue treatments were, rapeseed residues on the soil surface where rapeseed vegetative growth was cut and left on the soil (Rrs), rapeseed residues incorporated 10 to 12 cm deep, using two passes of a disc harrow (Rri), rapeseed residues incorporated in a 25 cm wide slot over the row at corn planting using a narrow cultivator attached to the planter (Rrs1), and no rapeseed residues (No Rr). In 1997, the slot incorporated (Rrs1) and rapeseed on the soil surface (Rrs) treatments were eliminated due to the strong interference with corn observed in 1996.

**Corn Establishment**

Corn Pioneer ‘3563’ was planted on June 10, 1996 and June 5, 1997 on the rapeseed residue treatments described above using a no-till planter with five units spaced 0.75 m apart, adjusted to plant 5 cm deep at a seeding rate of 70148 seeds ha\(^{-1}\).

**Weed control treatments for 1996.** Berseem clover and sava medic were planted two days after corn planting (DAP) at 200 seeds per linear meter, positioning the seeds approximately 7.5 cm on both sides of the corn row and 2.5 to 3.5 cm deep. A weedy control where weeds grew the entire season with corn and a hand weeded check were included.

**Weed control treatments for 1997.** Individual berseem clover and sava medic treatments were planted in a 25 cm band over the corn row at 200 seeds m\(^{-2}\) on June 5, followed by an inter-row cultivation 18 DAP. Individual treatments of berseem clover and sava medic were also planted broadcast between the corn rows at 200 seeds m\(^{-2}\) and
shallowly incorporated with a rake. A band postemergence herbicide mixture of 34 g a.i. ha\(^{-1}\) nicosulfuron plus 0.8 kg a.i. ha\(^{-1}\) atrazine, with crop oil concentrate at 1% (v/v), was applied 16 days after crop emergence using a backpack sprayer with TeeJet 11001E nozzles covering a 60 cm band between the corn rows, calibrated to apply 187 L ha\(^{-1}\). Inter-row cultivation conducted 18 DAP represented the sixth treatment, and weedy and hand weeded controls were included.

**Experimental Design and Evaluations**

Four rapeseed residue treatments and four weed control treatments resulted in 16 treatments for 1996. Two rapeseed residue treatments and the eight weed control treatments resulted in 16 treatments for 1997. Treatments were arranged as split plots in a complete randomized block with three replications in 1996 and four replications in 1997. Rapeseed residue treatments represented the main plots and the weed control treatments were the split plots.

Corn population density was determined by counting the number of plants per row, sampling two rows per plot. Corn height was measured from eight plants selected at random from the two center rows in each plot. Both parameters were determined 23 and 49 DAP in 1996, and 13, 28, and 47 DAP in 1997. Corn yield was determined on October 27, 1996 and October 29, 1997. The three center rows of each plot were harvested manually and grain removed from ears with a thresher and data converted to 15% moisture.

Weed density was determined by sampling six and four 0.1 m\(^2\) quadrats per plot, randomly selected at 23 and 49 DAP in 1996 and 18 and 32 DAP in 1997. Weed fresh weight measurements were made 60 and 56 DAP in 1996 and 1997, respectively. A third weed density evaluation was conducted 60 and 50 DAP in 1996 and 1997, respectively. The
third evaluation was done by sampling two 0.25 m² quadrats chosen randomly from the three center rows of each plot.

Smother crop densities were determined by sampling three and four 0.1 m² quadrats per plot randomly selected from the three center rows of each plot at 23, and 49 DAP and 18, and 32 DAP in 1996 and 1997, respectively. Smother crop fresh weight was determined 60 and 56 DAP in 1996 and 1997, respectively. A third evaluation of smother crop density was made 60 and 50 DAP in 1996 and 1997, respectively. Smother crop fresh weight and a third density evaluation were determined by sampling two 0.25 m² quadrats per plot selected randomly from the three center rows.

Statistical Analysis

Weed fresh weight, smother crop fresh weight, and corn yield data were subjected to ANOVA using a split plot in a complete randomized block design. ANOVA procedure was also used on population densities of weeds, smother crops, and corn and corn height data using a split-split plot in a complete randomized block design in which time was a repeated measurement. Means were separated by Fisher’s protected LSD test at P = 0.05, when differences were detected, using the appropriate error term based on significant main effects and interactions.

Results and Discussion

Rapeseed Establishment

In 1996, the rapeseed density was more than 1.8 million plants ha⁻¹ and produced 4480 kg ha⁻¹ fresh weight 46 DAP (Table 1). Rapeseed population in 1997 was 76% lower than the previous year. The higher population in 1996 was probably due to favorable soil moisture during establishment, compared to 1997. Considering a ten-day period from four
days before to five days after rapeseed replanting, the amount of precipitation accumulated in 1996 was 30 mm compared to 8.8 mm in 1997. In Iowa, temperatures early in April usually are cool (5 to 10°C) and soil moisture is rapidly lost from the soil surface due to soil preparation and seed incorporation. Temperature averages in the same period of time were 10 and 10.3°C for 1996 and 1997, respectively. The inconsistent results for spring cover crops establishment represents an important issue that needs more research in the Midwest (Buhler et al. 1998).

Rapeseed Smothering Action on Weeds

Rapeseed did not affect weed density or weed growth prior to corn establishment (Table 1). These results contrasted with Medina et al. (1997) who found that in soybeans, rapeseed reduced weed populations. Possible interactions among corn and soybean residues in the soil with rapeseed could explain the observed differences. The larger quantity of corn residue at soybean planting may have covered the ground and provided more and different allelochemicals that interacted with rapeseed vegetative growth resulting in more efficient control of weeds. The assumption that corn residue and rapeseed have allelopathic properties is widely supported (Anderson and Cruse 1995; Boydston and Hang 1995; Cole 1976).

Treatment Effects on Weed Population Dynamics and Corn Growth

Considerable corn and weed data, in response to rapeseed residue and weed control treatments, was collected and the statistical analyses were confounded by 2-way and 3-way interactions. The interpretation of the data was further confounded by changes in treatments and experiment location between 1996 and 1997. As a result, analyses were conducted separately by year and results will presented in that manner. Specific main effects and 2-way
interactions that were statistically significant will be discussed by year. A summary of the
data analyses is presented in Tables 2 and 3 to provide an overview of the research results.

Rapeseed residue management demonstrated no significant effect on weed population
density, however a consistent response was detected for weed control treatments. The 2-way
interactions between time and rapeseed residue management and weed control treatments
were not consistently significant. No significant 3-way interaction was detected. Consistent
responses of smother crops density and fresh weight to weed control treatments were
observed. Corn yield also was affected by weed control treatments in 1996 and 1997.

1996

**Effect on weed density.** Sava medic reduced total weeds and giant foxtail (*Setaria
faberi* Herrm.) densities when compared to berseem clover and weedy control treatments
(Table 4). Sava medic and berseem clover did not reduce the density of common
lambsquarters (*Chenopodium album* L.) when compared with the weedy control treatment.

*Amaranthus* spp. density was reduced by berseem clover and sava medic treatments
on rapeseed residues incorporated or slot incorporated treatments (Figure 1). High
*Amaranthus* spp. densities were found in the weedy control treatments without rapeseed
residues and where rapeseed residues were soil incorporated. Tillage in the no rapeseed and
rapeseed soil incorporated treatments may have stimulated the germination of *Amaranthus*
spp. Blackshaw et al. 1994 found greater redroot pigweed (*Amaranthus retroflexus* L.)
population density when soil was not disturbed thus the differences may be attributable to
different rotational patterns and environmental conditions. Rapeseed density increased over
time when rapeseed residues were slot incorporated because the rapeseed population was
allowed to grow between the corn rows. Density also increased in the rapeseed residue on
the soil surface treatment as a consequence of rapeseed regrowth (Figure 1).

**Treatment effect on weed and rapeseed fresh weight.** Total weed fresh weight was
reduced by rapeseed residues (Table 5). Boydston and Hang (1995) and Brown et al. (1991)
reported similar results. Rapeseed fresh weight increased when rapeseed residues were slot
incorporated compared to rapeseed on the soil surface and rapeseed incorporated treatments
(Table 5).

Rapeseed residues left on the soil surface reduced *Amaranthus* spp. fresh weight as
did slot incorporated residues regardless of the weed control treatments (Figure 2). Smother
crops did not reduce the total weed fresh weight (Table 6). *Amaranthus* spp. fresh weight
was also reduced by sava medic and berseem clover when rapeseed residues were soil
incorporated. *Amaranthus* spp. fresh weight increased over time in the absence of rapeseed
residues regardless of the weed control treatment (Figure 2).

**Smother crops density and growth.** Berseem clover had a higher density than sava
medic (Figure 3) but there were no differences in fresh weight production (Table 7).
Smother crop densities declined over time (Figure 3). Rapeseed residues on the soil surface
or slot incorporated caused a significant reduction in the smother crop fresh weight compared
with no rapeseed or rapeseed incorporated treatments (Table 7). Allelopathic effects of the
rapeseed residues and weed interference may explain the reduction in the smother crops fresh

**Corn population density and height.** Corn population density was not affected by
any of the treatments. Rapeseed residues on the soil surface and slot incorporated reduced
corn height 23 DAP and caused a 42% height reduction 49 DAP (Figure 4). The interference
imposed by rapeseed residues was reduced when residues were incorporated in the soil. These results were consistent with those of Boydston and Hang (1995) and Brown et al. (1991).

**Corn yield.** Rapeseed residues on the soil surface and slot incorporated treatments had the lowest corn yields. A 50% corn yield reduction occurred when rapeseed residues were left on the soil surface compared with no rapeseed (Table 8). It is possible that rapeseed allelopathy or physical competition reduced corn yield. Buhler et al. (1998) and De Haan et al. (1994) reported similar results. Sava medic had a corn yield comparable to the hand weeded treatment (Table 8). The positive effect of sava medic controlling weeds (Table 4) resulted in the high corn yield.

1997

**Effects on weed density.** Total weeds and *Amaranthus* spp. populations were reduced over time by berseem clover and sava medic followed by cultivation treatments, the banded herbicide treatment, and the cultivation treatment (Figure 5). Sava medic or berseem clover followed by cultivation were as effective as the banded herbicide treatment in controlling total weed populations. Weed density did not change over time when smother crops were seeded between the rows (Figure 5). Giant foxtail density was equally reduced by all the weed control treatments (Table 9).

**Effects on weed fresh weight.** Rapeseed residues on the soil surface or incorporated reduced total weed and Pennsylvania smartweed (*Polygonum pensylvanicum* L.) fresh weights (Table 10). Total weeds and giant foxtail fresh weights were also reduced by some weed control treatments (Table 11). Hand weeded and herbicide treatments had the highest weed fresh weight reductions. Berseem clover and sava medic seeded between the rows did
not reduce total weeds and giant foxtail fresh weight when compared with the weedy control treatment.

Berseem clover seeded between the rows and growing on rapeseed residues increased the fresh weight of *Amaranthus* spp. compared with the weedy control treatment (Figure 6). Berseem clover seeded over the row followed by cultivation, the banded herbicide treatment, and cultivation alone had the lowest *Amaranthus* spp. fresh weight. Rapeseed regrowth after the incorporation in the soil was reduced by sava medic seeded over the row followed by cultivation and the banded herbicide treatment compared with the rest of the weed control treatments (data not shown).

**Smother crops density and growth.** Berseem clover and sava medic population densities were reduced when rapeseed residues were incorporated into the soil compared with the no rapeseed treatment (Table 12). There was a poor establishment of sava medic and berseem clover in 1997 compared with 1996 due basically to lack of precipitation before and after smother crops planting. There was recorded an accumulation of 72 mm of water in a ten days period started before four and five days after planting date in 1996 compared with a 1 mm accumulated in the same period of time in 1997. Smother crops seeded over the row followed by cultivation treatments had lower densities 18 DAP than smother crops seeded between the rows (Figure 7). Soil disturbance caused by cultivation buried seedlings and reduced smother crop density.

**Corn density and height.** Corn density was not affected by any treatment in 1997. Corn height did not vary until 47 DAP when significant reductions occurred on the weedy control and berseem clover and sava medic, planted between the corn rows (data not shown). This late reduction of corn height was attributable to the lack of weed control and resultant
competition in these treatments. The fact that there were no differences in corn height early indicated the ability of corn to compete with weeds (Medina 1983; Nieto et al. 1968).

**Corn yield.** Corn yield reflected the efficacy of the weed control treatments (Table 13). The banded herbicide treatment and smother crops treatments seeded over the row and followed by cultivation had yields comparable to the hand weeded treatment. Further, smother crop treatments combined with cultivation resulted in no statistical differences in yield compared with cultivation alone. The positive effect on weed control by rapeseed residues, smother crops, herbicides, and cultivation suggests these strategies are alternatives for more sustainable weed control systems in corn production, as indicated by Buhler et al. (1998) and Williams et al. (1998).

**General Discussion**

Rapeseed established after re-seeding in 1996, but establishment was poor in 1997. Rapeseed vegetation prior to management treatments did not have any effect on weed population dynamics compared to no rapeseed. These results were contrary to those reported by Medina et al. (1997) in soybean. A physical effect of different crop residues and rapeseed vegetation and a possible chemical interaction between crop residue and rapeseed root exudates may be the causes of these differences. Corn residues usually are abundant and well distributed on the soil before soybean planting covering the ground and releasing allelopathic substances early in the spring, these two properties of corn residue may have interacted with rapeseed vegetative growth and provided better weed control than when corn was planted in fields with soybean residues.

Sava medic and berseem clover establishment was successful in 1996 due to favorable soil moisture, but not in 1997. As Buhler et al. (1998) indicated, the frequency of
establishment failures increased with later planting times, probably due to increased temperatures that dry the soil surface. Smother crop seeding after corn planting by spreading seeds on the soil surface followed by shallow incorporation was not an efficient method of establishment.

In 1996, weed density was low and was further reduced by a smother crop of sava medic. In 1997, smother crop treatments planted over the row and followed by cultivation, as well as the banded herbicide treatment reduced densities of total weed species and *Amaranthus* spp. Rapeseed residues reduced weed fresh weight in both years. In 1996, smother crops did not affect weed fresh weight. In 1997, the banded herbicide treatment caused the highest reduction of total weed fresh weight, followed by the smother crops planted over the row and cultivated. Smother crop density and fresh weight were negatively affected by rapeseed residue treatments and by cultivation in 1997.

Corn density was not affected by any treatment. Rapeseed residues on the soil surface or slot incorporated in 1996 affected corn height, but there was no effect when rapeseed residues were incorporated. The efficacy of rapeseed residue and weed control treatments on weed densities and rapeseed interference on corn growth influenced corn yield. In 1997, the banded herbicide treatment and smother crops seeded over the row followed by cultivation had yields comparable to the hand weeded check.

**Conclusions**

Rapeseed residues affected weeds, smother crops, and corn densities and growth, particularly when rapeseed was cut and left on the soil surface. Crop residues, rapeseed management, tillage, smother crops, and herbicides were components of the crop production system that affected the weed population dynamics. The weed control efficacy of rapeseed
treatments as well as the effect of rapeseed interference on corn growth determined corn yield. Spring rapeseed cover crop with sava medic over the corn row and supplemented with cultivation or a banded postemergence herbicide treatment represent alternatives for weed control in corn. More research must be conducted screening cover crop species adaptability to environmental conditions, breeding the species that have shown potential, and searching for agronomic practices that could enhance cover crop establishment under stressful conditions to develop cover crop systems for the Midwest US.

**Literature Cited**


Nieto, J., M.A. Brando and J.T. Gonzalez. 1968. Critical periods of the crop growth cycle for competition from weeds. PANS (C) 14:159-166.


Table 1. Effect of rapeseed on weed density and fresh weight prior to corn establishment.

<table>
<thead>
<tr>
<th>Rapeseed</th>
<th>Total weed</th>
<th>Weed density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Density</td>
<td>Fresh Weight</td>
</tr>
<tr>
<td></td>
<td>Plants ha(^{-1}) (x 1000)</td>
<td>kg ha(^{-1})</td>
</tr>
<tr>
<td>with rape</td>
<td>1810 a*</td>
<td>4880 a</td>
</tr>
<tr>
<td>1996</td>
<td>0 b</td>
<td>0 b</td>
</tr>
<tr>
<td>no rape</td>
<td>440 a</td>
<td>8210 a</td>
</tr>
<tr>
<td>1997</td>
<td>0 b</td>
<td>0 b</td>
</tr>
</tbody>
</table>

* Values with same letter are not significantly different at the P ≤ 0.05 level. These means are only comparable within same column and within the same year.

**Common lambsquarters (Chenopodium album); Giant foxtail (Setaria faberii); Pennsylvania smartweed (Polygonum pensylvanicum).
Table 2. Summary of the sources of variation from the analyses of variance for weed, rapeseed, and smother crop density and fresh weight and crop density, height and yield in corn during 1996.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source</th>
<th>Rrm</th>
<th>Wct</th>
<th>Rrm by Wct</th>
<th>Time</th>
<th>Time by Rrm</th>
<th>Time by Wct</th>
<th>Time by Rrm by Wct</th>
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<td>NS</td>
<td>NS</td>
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<tr>
<td>Giant foxtail</td>
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<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
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<tr>
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<td>NS</td>
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<td>*</td>
<td>NS</td>
<td>**</td>
<td>NS</td>
<td>*</td>
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</tr>
<tr>
<td>Pennsylvania smartweed</td>
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<td>NS</td>
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<td>NS</td>
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<td>NS</td>
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<td>Total weed species</td>
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<tr>
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<tr>
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<tr>
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<tr>
<td>Rapeseed</td>
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<td>NS</td>
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<td></td>
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<tr>
<td>Smother crops</td>
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<tr>
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<tr>
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<td>NS</td>
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*a* Rrm, rapeseed residue management; Wct, Weed control treatments.

*b* *F*-test significant at: * = 0.05, ** = 0.01, NS = not significant at P > 0.05, na = not applicable
Table 3. Summary of the sources of variation from the analyses of variance for weed, rapeseed, and smother crop density and fresh weight and crop density, height and yield in corn during 1997.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source(^a)</th>
<th>Source(^a)</th>
<th>Source(^a)</th>
<th>Source(^a)</th>
<th>Source(^a)</th>
<th>Source(^a)</th>
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<td></td>
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<td></td>
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<tr>
<td>Total weed species</td>
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<td>**</td>
<td>NS</td>
<td>**</td>
<td>NS</td>
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</tr>
<tr>
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<td>**</td>
<td>NS</td>
<td>**</td>
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</tr>
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<td>NS</td>
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<td>Total weed species</td>
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<td>Smother crops</td>
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<td>Density</td>
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<td>Yield</td>
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<td>**</td>
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</tbody>
</table>

\(^a\) Rm, rapeseed residue management; Wct, Weed control treatments.

\(^b\) F-test significant at: * = 0.05, ** = 0.01, NS = not significant at P > 0.05, na = not applicable.
Table 4. Effect of weed control treatments on weed density in corn, 1996a.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total weed</th>
<th>Giant foxtail</th>
<th>Common lambsquarters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berseem clover</td>
<td>28</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Sava medic</td>
<td>20</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Weedy</td>
<td>31</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Hand weeded</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>8</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

a Means averaged over four rapeseed (Brassica napus L.) residue treatments and three evaluation times, representing 36 observations.

b Setaria faberi Herrm.

c Chenopodium album L.

d Tifolium alexandrinum L.

e Medicago scutellata L.
Table 5. Effect of rapeseed (*Brassica naphus* L.) residue management on weed fresh weight 60 DAP\(^a\) in corn, 1996.

<table>
<thead>
<tr>
<th>Rapeseed residue management (^b)</th>
<th>Total weeds (\text{g m}^{-2})</th>
<th>Rapeseed (\text{g m}^{-2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>On the soil surface</td>
<td>219</td>
<td>428</td>
</tr>
<tr>
<td>Soil incorporated</td>
<td>354</td>
<td>178</td>
</tr>
<tr>
<td>Slot incorporated</td>
<td>103</td>
<td>1682</td>
</tr>
<tr>
<td>No rapeseed</td>
<td>892</td>
<td>0</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>432</td>
<td>612</td>
</tr>
</tbody>
</table>

\(^a\) DAP = Days after planting  
\(^b\) Means averaged over four weed control treatments representing 12 observations.
Table 6. Effect of weed control treatments on total weeds fresh weight 60 DAP\(^2\) in corn, 1996.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total weeds g m(^{-2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berseem clover(^b)</td>
<td>381(^c)</td>
</tr>
<tr>
<td>Sava medic(^d)</td>
<td>481</td>
</tr>
<tr>
<td>Weedy check</td>
<td>698</td>
</tr>
<tr>
<td>Hand weeded check</td>
<td>9</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>348</td>
</tr>
</tbody>
</table>

\(^{1}\)DAP = Days after planting.  
\(^{2} Trifolium alexandrinum \text{ L.}\)  
\(^{3}\) Means averaged over four rapeseed residue treatments representing 12 observations.  
\(^{4} Medicago scutellata \text{ L.}\)
Table 7. Effect of rapeseed (*Brassica naphus* L.) residues and weed control treatments on smother crops fresh weight 60 DAP<sup>a</sup> in corn, 1996.

<table>
<thead>
<tr>
<th>Rapeseed residue management</th>
<th>Smother crops</th>
<th>g m&lt;sup&gt;-2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>On the soil surface</td>
<td>60&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Soil incorporated</td>
<td>156</td>
<td></td>
</tr>
<tr>
<td>Slot incorporated</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>No rapeseed</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>51</td>
<td></td>
</tr>
</tbody>
</table>

| Weed control                         |               |                |
| Berseem clover<sup>c</sup>           | 214<sup>d</sup>|                |
| Sava medic<sup>e</sup>               | 160           |                |
| LSD (0.05)                           | 98            |                |

<sup>a</sup> DAP = Days after planting.
<sup>b</sup> Means averaged over two smother crop species, four weed control treatments representing 24 observations.
<sup>c</sup> *Trifolium alexandrinum* L.
<sup>d</sup> Means averaged over four rapeseed residue treatments representing 12 observations.
<sup>e</sup> *Medicago scutellata* L.
Table 8. Effect of rapeseed (*Brassica naphus* L.) residues and weed control treatments on corn yield in 1996.

<table>
<thead>
<tr>
<th>Rapeseed residue management</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>On the soil surface</td>
<td>2086(^a)</td>
</tr>
<tr>
<td>Soil incorporated</td>
<td>4819</td>
</tr>
<tr>
<td>Slot incorporated</td>
<td>354</td>
</tr>
<tr>
<td>No rapeseed</td>
<td>4259</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>1623</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weed control treatments</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Berseem clover(^b)</td>
<td>1560(^c)</td>
</tr>
<tr>
<td>Sava medic(^d)</td>
<td>2113</td>
</tr>
<tr>
<td>Weedy check</td>
<td>1968</td>
</tr>
<tr>
<td>Hand weeded check</td>
<td>2880</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>846</td>
</tr>
</tbody>
</table>

\(^a\) Means represent the average from three replications on the same rapeseed residue treatment.  
\(^b\) *Trifolium alexandrinum* L.  
\(^c\) Means averaged over four rapeseed residue treatments representing 12 observations.  
\(^d\) *Medicago scutellata* L.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Giant foxtail density</th>
<th>plants m⁻²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berseem clover banded over the row plus cultivation</td>
<td>386</td>
<td></td>
</tr>
<tr>
<td>Sava medic banded over the row plus cultivation</td>
<td>439</td>
<td></td>
</tr>
<tr>
<td>Berseem clover between the rows</td>
<td>576</td>
<td></td>
</tr>
<tr>
<td>Sava medic between the rows</td>
<td>367</td>
<td></td>
</tr>
<tr>
<td>Banded herbicide</td>
<td>305</td>
<td></td>
</tr>
<tr>
<td>Cultivation</td>
<td>509</td>
<td></td>
</tr>
<tr>
<td>Weedy check</td>
<td>652</td>
<td></td>
</tr>
<tr>
<td>Hand weeded</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>298</td>
<td></td>
</tr>
</tbody>
</table>

a Means averaged over time and by rapeseed residue treatments, representing 32 observations.

b Berseem clover (*Trifolium alexandrinum* L.).

c Sava medic (*Medicago scutellata* L.)
Table 10. Effect of rapeseed (*Brassica naphus* L.) residue management on weed fresh weight 60 DAP, in corn 1997.

<table>
<thead>
<tr>
<th>Rapeseed residue management(^b)</th>
<th>Total weeds (\text{g m}^{-2})</th>
<th>Pennsylvania smartweed(^c) (\text{g m}^{-2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil incorporated</td>
<td>3028</td>
<td>32</td>
</tr>
<tr>
<td>No rapeseed</td>
<td>3650</td>
<td>106</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>586</td>
<td>58</td>
</tr>
</tbody>
</table>

\(^a\) DAP = Days after planting.
\(^b\) Means averaged over eight weed control treatments, representing 32 observations.
\(^c\) Pennsylvania smartweed (*Polygonum pensylvanicum* L.).
Table 11. Effect of weed control treatments on weed fresh weight 60 DAP, in corn 1997.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Total weeds</th>
<th>Giant foxtail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berseem clover over the row plus cultivation</td>
<td>3028</td>
<td>2804</td>
</tr>
<tr>
<td>Sava medic over the row plus cultivation</td>
<td>3360</td>
<td>2776</td>
</tr>
<tr>
<td>Berseem clover between the rows</td>
<td>5892</td>
<td>4764</td>
</tr>
<tr>
<td>Sava medic between the rows</td>
<td>6168</td>
<td>5224</td>
</tr>
<tr>
<td>Banded herbicide</td>
<td>668</td>
<td>524</td>
</tr>
<tr>
<td>Cultivation</td>
<td>2800</td>
<td>2272</td>
</tr>
<tr>
<td>Weedy check</td>
<td>4800</td>
<td>4152</td>
</tr>
<tr>
<td>Hand weeded check</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>1408</td>
<td>1440</td>
</tr>
</tbody>
</table>

* DAP = Days after planting.
* Means averaged over two rapeseed residue treatments, representing 8 observations.
* * Setaria faberi L. 
* * Trifolium alexandrinum L. 
* * Medicago scutellata L. 
*

<table>
<thead>
<tr>
<th>Rapeseed residue management&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Smother crops&lt;sup&gt;b&lt;/sup&gt;</th>
<th>plants m&lt;sup&gt;-2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil incorporated</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>No rapeseed</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

<sup>a</sup> Means averaged over eight weed control treatments and by four evaluation time, representing 96 observations.

<sup>b</sup> Means averaged over berseem clover (*Trifolium alexandrinum* L.) and sava medic (*Medicago scutellata* L.).
Table 13. Effect of weed control treatments on corn yield in 1997^a.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berseem clover over the row plus cultivation</td>
<td>7311</td>
</tr>
<tr>
<td>Sava medic over the row plus cultivation</td>
<td>7064</td>
</tr>
<tr>
<td>Berseem clover between the rows</td>
<td>4219</td>
</tr>
<tr>
<td>Sava medic between the rows</td>
<td>4246</td>
</tr>
<tr>
<td>Banded herbicide</td>
<td>8325</td>
</tr>
<tr>
<td>Cultivation</td>
<td>6783</td>
</tr>
<tr>
<td>Weedy check</td>
<td>4340</td>
</tr>
<tr>
<td>Hand weeded check</td>
<td>8100</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>1364</td>
</tr>
</tbody>
</table>

^a Means averaged over two rapeseed residue treatments, representing eight observations.

b *Trifolium alexandrinum* L.

c *Medicago scutellata* L.
Figure 1. Effect of rapeseed (*Brassica naphus* L.) residue management and weed control treatments on rapeseed and weed population densities in corn 1996. Rrs = Rapeseed residue on the soil surface, Rri = rapeseed residue soil incorporated, RrsI = Rapeseed residue slot incorporated, NoRr = No rapeseed residue. Berseem clover (*Trifolium alexandrinum* L.), Sava medic (*Medicago scutellata* L.). (Means averaged over three evaluation times, representing nine observations).
Figure 2. Effect of the rapeseed (*Brassica naphus* L.) residue management and weed control treatments on *Amaranthus* sp. fresh weight 60 DAP, in corn 1996. Rrs = Rapeseed residue on soil surface, Rri = Rapeseed residue soil incorporated; RrsI = Rapeseed residue slot incorporated, NoRr = No rapeseed residue, DAP = days after planting. Berseem clover (*Trifolium alexandrinum* L.), Sava medic (*Medicago scutellata* L.). (Means represent three observations).
Figure 3. Effect of evaluation time on smother crop density in corn, 1996. Berseem clover (*Trifolium alexandrinum* L.), Sava Medic (*Medicago scutellata* L.). DAP= Days after planting. (Means averaged over four rapeseed residue treatments, representing 12 observations).
Figure 4. Effect of rapeseed (*Brassica napus* L.) residue management and evaluation time on corn height in 1996. 

Rrs = Rapeseed residue on the soil surface, Rri = Rapeseed residue soil incorporated, RrsI = Rapeseed residue slot incorporated, No Rr = No rapeseed residue. DAP = Days after planting. (Means averaged over four weed control treatments, representing 12 observations).
Figure 5. Effect of weed control treatments and evaluation time on weed density in corn 1997.

Abbreviations: Be Cl Cu = Berseem clover (*Trifolium alexandrinum* L.) plus cultivation, Sa Me Cu = Sava medic (*Medicago scutellata* L.) plus cultivation, Be Cl br = Berseem clover planted between crop row, Sa Me br = Sava medic planted between the crop row, DAP = Days after planting. (Means averaged over two rapeseed residue treatments, representing eight observations).
Figure 6. Effect of rapeseed (*Brassica campestris* L.) residue management and weed control treatments on *Amaranthus* spp fresh weight 60 DAP in corn, 1997. a Abbreviations: Be Cl Cu = Berseem clover (*Trifolium alexandrinum* L.) plus cultivation, Sa Me Cu = Sava medic (*Medicago scutellata* L.) plus cultivation, Be Cl br = Berseem clover planted between the crop row, Sa Me br = Sava medic planted between the crop row, Rri = Rapeseed residue soil incorporated, No Rr = No rapeseed residue, DAP= days after planting. (Means represent four observations).
Figure 7. Effect of weed control treatments and evaluation time on smoother crop density in corn, 1997.

Abbreviations: Be Cl Cu = Berseem clover (*Trifolium alexandrinum* L.) plus cultivation, Sa Me Cu = Sava medic (*Medicago scutellata* L.) plus cultivation, Be Cl br = Berseem clover planted between the crop row, Sa Me br = Sava medic planted between crop row, DAP = Days after planting. (Means averaged over two rapeseed residue treatments, representing eight observations).
GENERAL CONCLUSIONS

Rapeseed establishment was successful in 1996 after replanting but poor in 1997. Low soil moisture content, tillage, and warm temperatures at planting time were critical factors in the failure of cover crop establishment in 1997 (Buhler et al. 1998). Rapeseed vegetation reduced weed density, weed fresh weight, and affected weed species composition before soybeans were planted, but there were no differences in corn. A larger quantity of corn residue covered the ground before soybean planting compared with soybean residues present in fields where corn was planted. The physical and allelopathic action of corn residues may have interacted with rapeseed vegetation and root exudates resulting in more effective control of the weed community (Anderson and Cruse 1995; Boydston and Hang 1995).

Sava medic and berseem clover establishment was successful in 1996. Low soil moisture at planting time compromised smother crop establishment in 1997. The smother crop planting method of spreading seeds on the soil surface followed by shallow incorporation was not efficient. No tillage seeding of smother crops may be an option to enhance establishment since the no soil disturbance and the presence of more residue on the soil surface would improve soil moisture on the soil surface, which was an important factor in cover crops establishment.

In 1996, the smother crops and rapeseed residues reduced weed density in soybean. In corn, weed pressure was low and was reduced further by sava medic. In 1997, berseem clover and sava medic seeded over the row and followed by cultivation, as well as the banded herbicide treatment reduced weed densities in corn and soybean.
Rapeseed residues reduced weeds and smother crops fresh weight, as well as corn and soybean height, particularly where rapeseed residues were on the soil surface. In 1997, the banded herbicide treatment caused the greatest reduction in weed fresh biomass. Berseem clover and sava medic planted over the row followed by cultivation were more effective than cultivation alone for weed control. Soybean and corn yields were consistent with the efficacy of the weed control treatments. Corn yield differed between rapeseed on the soil surface compared with no rapeseed residue due to the extreme susceptibility that corn had to the presence of these residues.

This research reported the effectiveness of cover crops established before and with soybean and corn on weed control when properly combined with cultivation or herbicides. Further work needs to be done to improve cover crop establishment, which is a critical issue in their success as a tool in weed control. Agronomic practices such as planting dates and planting methods in no tillage systems combined with the use of soil amendments may be important areas for further research. A breeding program for those species that have shown promising results and a broad screening of potential cover crop species to improve adaptability, should be another priority to improve the use of cover crops for weed control in corn and soybean production systems.
APPENDIX: EFFECT OF TEMPERATURE AND SEED TREATMENT ON THE GERMINATION AND ESTABLISHMENT OF RAPESEED (*BRASSICA NAPHUS*)

**Abstract**

Rapeseed establishment experiments were conducted in growth chambers in 1998. Seed treatments, and nitrogen and phosphorous fertilization were tested alone or in combination to determine their effect on rapeseed establishment under cold temperatures. Rapeseed emergence and growth rate increased at 10 C when compared with 5 C. Cold temperatures delayed the emergence of rapeseed. Phosphorous fertilization and carboxin, metalaxyl, and fludioxonil seed coating enhanced rapeseed emergence and growth. Nitrogen fertilization did not have a positive effect on rapeseed establishment.

**Introduction**

Cover crops are an alternative method for weed control, protect soils against erosion, and improve soil quality (Buhler et al. 1996; Lal et al. 1991). The lack of winter hardiness in cover crops has limited utilization in the North Central region of the United States when established in the fall but better chances of success may be with spring establishment (Lal et al. 1991; Wyse 1994).

Rapeseed (*Brassica naphus* L.) was seeded early in the spring and various rapeseed residue management strategies were tested for weed control in corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] (Medina 1997; Medina et al. 1997). Limitations in soil moisture and low temperature were probably responsible for poor rapeseed and smother crops establishment reported by Medina (1997) and Medina et al. (1997). Despite
establishment problems, rapeseed residues affected weed population dynamics by reducing weed density and growth. Thus, it is important to develop knowledge about cover crop germination and the environmental conditions that enhance establishment and potentially improve weed control.

To determine whether or not low temperature influenced rapeseed establishment and how the addition of soil amendments and seed coating could enhance rapeseed emergence and growth under low temperatures, experiments were conducted in growth chamber in 1998.

**Rapeseed establishment and environment**

The establishment of small-seeded crops is a well-known problem and there are limited options to overcome the problem. Environmental factors, biological components, agronomic practices, and possible interactions influence seedling establishment (Murray et al. 1987; Pollock and Eagles 1988). Some smother crop species and forage plants resemble weeds given their small seed size. However, smother crops do not have the genetic plasticity normally found in weeds thus potentially limiting their success in a variable environment and more limitations for smother crops establishment may be expected to occur (Harper 1977).

Rapeseed is generally seeded in the spring in Canada when the growing conditions are notoriously variable and newly emerging seedlings may be exposed to low temperatures, frost, dry soils, and occasional heat waves (Anonymous 1995). Under such adverse conditions, germination may be spotty and seedling growth poor, leading to poor establishment and yield reductions. The early spring weather conditions in Iowa resemble those described for Canada (Dixon 1997).
Ecology of the seed establishment

Seedling population is a function of seed density and the frequency of "safe sites" that guarantee an adequate environment for a specific seed (Harper 1977). Harper (1977) defined "safe site" as that soil zone in which a seed may find the conditions for breaking dormancy, germination, and the absence of hazards. Harper and Benton (1966) showed that seed size and shape for several species were important for germination at different water tensions. They indicated that the seed contact with the water in the soil pores and the seed coat characteristics explained the variation in establishment among species.

Soil microtopography is another factor that could affect the germination of small-seeded species. Rapeseed and common lambsquarters emergence differs on soil surfaces. Common lambsquarters seed has a tuberculate and rough form and consistently remains at the position of the first landing contrasting with the smooth round seeds of rapeseed that rolls down easily into the crevices after they land on the soil (Harper et al. 1965). This means that rapeseed seeds may be better positioned in the soil surface compared with other small seeded crops.

Effect of temperature

Rapeseed is considered a relatively cool season crop with a minimum temperature for growth of 5 C and an optimum above 12 C and below 30 C. The optimum temperature for rapeseed growth and development is considered 20 C (Anonymous 1995). Research at the Agriculture and Agri-Food Canada Research Station, in Saskatoon, showed a drastic reduction in rapeseed seed germination at temperatures below 10 C compared with 20 C in growth chambers 6 days after planting. Rapeseed and *Brassica rapa* were sensitive to cold soil temperatures reducing their germination capacity and delaying the time period to obtain
50% germination. Under field conditions, trials conducted with 4 C soil temperature, seedlings required up to 18 days to emergence. Based on these studies, 10 C would be the minimum temperature for rapeseed seeding to obtain a high germination percentage and fast emergence (Anonymous 1997).

**Disease management**

The incidence of *Rhizoctonia solani*, *Fusarium*, and *Pythium* species during rapeseed establishment increased in cold soil particularly when the soil seedbed was not firmly packed after the small-seeded crop was planted. Seed quality, fungicides, depth of seeding, soil temperature above 10 C, and soil compaction after seeding are important factors that could prevent the disease attack (Anonymous n/d).

**Fertilization**

An adequate supply of phosphorus enables the plant to develop a strong, healthy root system in the early growth stages. Early vigorous rooting increases overall use of moisture and nutrients promoting early vegetative growth and the development of larger seedlings. The negative effect of low temperature on crops could be diminished with appropriate levels of phosphorous in the soil (Anonymous 1997). Vigorous, actively growing plants with adequate phosphorus are also more able to withstand stresses from weather, disease, and insects. Minimum application levels of phosphorus are 10 to 15 kg ha\(^{-1}\) (Anonymous 1997). Nitrogen fertilization has positive effect on rapeseed growth as well as on many weed species (Vengris et al. 1995; Zimdahl 1980).
Seed coating

Seed coatings can protect seeds and seedlings from the negative effects of diseases and pests. Seeds are coated with fungicides, insecticides or other biological substance that enhance seed germination, seedling emergence and establishment (Anonymous b n/d).

Materials and Methods

In order to determine the effects of low temperatures, seed coating, and N and P fertilization on the germination and growth of rapeseed, growth chamber experiments were conducted during the spring of 1998 in the Agronomy greenhouse at Iowa State University.

Rapeseed treatments and experiment conditions

Rapeseed (variety 'Dwarf Essex') seeds were germinated in growth chamber at 5°C and 10°C. Light radiation was maintained at 250 μmol m⁻² s⁻¹ of PPFD. The photoperiod and relative humidity were maintained at 12/12 hours dark/light, and 90%, respectively. Seeds were placed in plastic pots and filled with 1200 g of dry field soil. Ten seeds were planted 2.5 cm deep in each pot. The soil was a Clarion loam (Fine-loamy, mixed, mesic Typic Hapludolls) with 4% O.M. Pots were placed in the growth chambers for three days to stabilize the soil and growth chamber temperature before planting. After seeding, each pot was watered to field capacity and moisture content maintained by watering every three days.

Treatments included rapeseed with and without amendments and seed coatings. Several treatments had rapeseed treated with a seed coating film alone or in combination with different amendments applied to the soil. The seed-coating included mixtures of fungicides fludioxonil [4-(2,2-difluoro-1,3-bendodioxol-4-yl)pyrrole-3-carbonitrile] and metalaxyl [N-(2,6-dimethylphenyl)-N-(methoxyacetyl)alanine methyl ester] at 2.5 g and 20 g, respectively in 100 kg of seed and carboxin (5,6-dihydro-2-methyl-N-phenyl-1,4-oxathiin-3-
carboxamide) at 64 g in 45.4 kg of seed. Other components of the coating film were CaCO₃ at 0.5 g for 10 g of seed and Seppic Polymer 25 ml at 10% solid.

Phosphorous treatments (30 and 60 kg ha⁻¹) were tested alone or with seed coating. Phosphorous was applied on the soil surface using a 46% concentration of triple calcium phosphate. Nitrogen (10 kg ha⁻¹) was applied alone or with phosphorous (30 kg ha⁻¹).

Combination treatments of nitrogen (10 kg ha⁻¹) with seed coating, and with seed coating plus phosphorus (30 kg ha⁻¹) also were tested. Nitrogen was applied on the soil surface using a 46% concentration of urea.

**Experimental design and evaluations.** Treatments were arranged in a complete randomized design with five replications and a pot represented the experimental unit. The experiment at 5 C continued for 50 d while the 10 C experiment continued 25 d.

Rapeseed density was determined 16, 18, 23, 28, 34, and 50 days after planting (DAP) and 4, 6, 9, 12, 15, and 25 DAP for the 5 C and 10 C experiments, respectively. At the end of each experiment, plants were cut at the soil surface and fresh weight was determined. Plants were then dried in an oven at 100 C for 24 hours and dry weight measured. Experiments were conducted twice.

**Statistical analysis.** Data was analyzed using the SAS program (SAS 1988) for analysis of variance. Fresh and dry weights data were analyzed using a complete randomized design model. Rapeseed density was evaluated over time and analyzed as split plot in a complete randomized design considering time as a repeated measure. When significant differences among treatments were detected, means were separated with Fisher’s least significant difference (LSD) test (P< 0.05).
Results and Discussion

Effect of temperature on rapeseed emergence

Rapeseed emergence increased with temperatures from 5 to 10 C, reaching the highest values 12 DAP at 10 C, and 28 DAP at 5 C (Figure 1). Rapeseed emergence started 16 DAP at 5 C, and 4 DAP at 10 C. A similar study reported that under field conditions, rapeseed germination and emergence was delayed until 18 DAP in soils at 4.5 C (Anonymous 1997).

Approximately 90% of the rapeseed emerged indicating temperature should not be considered a limiting factor in terms of the final rapeseed density (Figure 1). Rapeseed and *Brassica rapa* emergence was reduced drastically at temperatures below 10 C in studies conducted at the Agricultural and Agri-Food Canada Research Station in Saskatoon (Anonymous 1997). However, the 15-day experiment was too short to show a delay in the rapeseed emergence due to the cold temperature. Rapeseed at 5 C soil temperature emerged from the soil but chances for rapeseed establishment success improve as soil temperature increased above 10 C.

Effect of seed treatments on rapeseed emergence

Rapeseed population was affected by seed treatments regardless of temperature (Figure 2). At 5 C, none of the seed treatments increased rapeseed density when compared to the control (rapeseed alone). Rapeseed density was reduced at the high rate of phosphorous or with the low rates of P and N combined (Figure 2). At 10 C, rapeseed emergence increased in all the treatments compared to rapeseed alone. Seed coating may have protected seeds from the soil environment enhancing stress tolerance to cold soils and protecting seeds against diseases (Anonymous b no date).
**Rapeseed total fresh and dry weights.** A significant increase in fresh and dry weight occurred when temperature increased from 5 to 10 C (Figure 3). Rapeseed fresh and dry weight for the rapeseed alone increased 4 and 2 fold, respectively, when temperature increased from 5 to 10 C. A 100% increase in the fresh weight occurred at 5 C for rapeseed with seed coating and phosphorous, seed coating and nitrogen, or nitrogen and phosphorus treatments when compared with rapeseed alone. At 10 C, treatments with phosphorous alone, phosphorous and seed coating, or phosphorous and nitrogen increased the total fresh weight by 75% compared to rapeseed alone.

Phosphorous fertilization increased rapeseed growth under cool temperatures where soils usually exhibit low levels of available mineral nutrients (Korner and Larcher 1988). Hinsinger (1998) said the ability of rapeseed roots to utilize P could be related to the excretion of protons by roots, which acidify the soil environment, thus promoting the solubilization of carbonate apatite. Hubel and Beck (1993) attributed the P rhizosphere accumulation to the phosphatase enzyme activity excreted by plant roots that could solubilize the inorganic P present in the soil. This phenomenon of P accumulation could enhance P uptake in cold temperatures where the adsorption and desorption process is limited.

The seed coating, combined with fertilization, showed a consistently favorable pattern for rapeseed growth. The mixture of fungicide included in the seed coating likely can protect rapeseed seedlings from root diseases thus permitting better establishment.

**Conclusions**

This research showed that cold temperatures did not affect the final rapeseed population. However, temperatures near 5 C can delay emergence up to four weeks. Rapeseed emergence and growth rate increased at 10 C, suggesting that this temperature
could be a good indicator for rapeseed establishment. Phosphorous fertilization and seed coating enhanced rapeseed emergence and growth and could enhance spring rapeseed establishment in the Midwest. Considering the economic and technological aspects in the adoption of these results, the use of phosphorous alone could be a good strategy to enhance rapeseed establishment.
Figure 1. Effect of temperature on time of rapeseed emergence. Values within the same temperature followed by a common letter are not significantly different at the $P \leq 0.05$ level. (Means represent 100 observations).
Figure 2. Effect of seed treatments and temperature on rapeseed (*Brassica naphus* L.) emergence in the growth chamber. Values within the same temperature followed by a common letter are not significantly different at the $P \leq 0.05$ level. (Means represent 10 observations).
Figure 3. Effect of seed treatments and temperature on rapeseed (*Brassica napus* L.) fresh and dry weights, in the growth chamber. Values within the same temperature and same parameter followed by a common letter are not significantly different at the $P \leq 0.05$ level. (Means represent 10 observations).
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ACKNOWLEDGMENTS

I would like to thank Drs. Micheal Owen and Douglas D. Buhler for guidance and support during all my program of study. Their assistance goes well beyond what words can express. I give my sincere appreciation for the technical assistance provided by Madona Foster and Keith Kohler. I would like to thank my committee members Drs. Bob Hartzler, Tom Jurik, and John Obrycki for serving on my graduate committee. I would like to thank Dr. Paul Hinz, Department of Statistic, ISU, for statistical assistance throughout this research. Many thanks to Drs. Joseph Burris, Robert Horton, Agronomy Department, ISU, for facilitating their laboratories in the seed coating procedure and soil moisture determination, respectively. I would like to thank Dr. Richard Carlson for his support providing me with weather information. I have to thank all my fellow graduate students for their friendship. I would like to thank Iowa State University for the Scholarship that supported my program of studies. I would also like to acknowledge the Fulbright-Garcia Robles Fundation and Universidad Autonoma Chapingo for their economical support during my Ph.D. program.