Impact of Rotation on Yield and Economic Performance of Summer Crops-Winter Canola Cropping Systems

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ABSTRACT

In the southeast US, winter wheat as a double crop has proved to be economically profitable and beneficial for soil management to the farmers. Winter canola (Brassica napus L.) also has similar potential but its suitability as a double and in rotation with summer crops has not been evaluated. Therefore, performance of winter canola in rotation and as a double crop with soybean, corn, sorghum, and cotton were evaluated for two years. Results showed that effect of rotation on plant density during both the years was significant. Rotational effects on number of pods per plant were non-significant than canola grown as fallow in 2003 but not in 2004. Canola grown after soybean produced significantly higher seed yield in 2003 (2739 kg ha$^{-1}$) and 2004 (3129 kg ha$^{-1}$) than after other crops except corn (2938 kg ha$^{-1}$) and fallow (2876 kg ha$^{-1}$). Planting canola after fallow gave significantly the lowest economic returns during both the years. Canola gave significantly higher economic returns when planted after corn ($1237$) and cotton ($1169$) than soybean-canola and sorghum-canola and fallow-canola rotations in 2003. Similarly, cotton-canola ($1442$) and soybean-canola ($1393$) gave significantly higher economic returns per hectare than corn-canola, sorghum-canola, and fallow-canola cropping systems.

Keywords: canola, oilseed rape, rotation, summer crops

Introduction

Oilseed rape (Brassica related species) is now the second largest oilseed crop in the world and has passed peanut, sunflower and cottonseed in world’s oil supply. Out of the two species, Brassica napus L. and B. rapa L., winter type B. napus is the main oilseed rape crop in Europe and in parts of China. Spring type B. napus is produced in Canada and northern Europe. In Australia and the southeastern United States, where winters are mild, spring type B. napus can be grown as a fall-planted winter crop; however, its production in the southern US is relatively rare. Summer crops of cotton (Gossypium hirsutum L.), peanut (Arachis hypogaea L.), corn (Zea mays L.), and soybean (Glycine max (L.) Merr.) are the main southeastern row-crop and except for wheat, and to some extent rye and barley, no winter crop, particularly a cash crop like canola has been tried in rotation with summer crops.

Crop rotation is a system that increases crop yields. A biennial rotation of soybean and grain sorghum has also been used effectively to enhance yields (Dabney et al., 1988). In the midwestern USA, a biennial rotation of corn (Z. mays L.) and soybean produced significant increases in the yields of both crops (Meese et al., 1991). The cause of the higher yields is either related to increased soil fertility, improved soil physical properties, weed control, or reduced incidences of disease, nematode, and insect pests (Crookston, 1995). Crop diversification provides more control opportunities and disrupts life cycles of weeds that are crop mimics (Anderson, 1997).
Guy (1999) observed that canola provides greater production potential and reduced disease levels in subsequent winter wheat crops when compared to wheat or barley. Grain legumes and some *Brassica* species are important in sustainable cropping systems that optimize crop production and its crop residue to minimize soil erosion. Gregory (1997) established that successful crops of oilseeds and lupin can be grown on soils with adequate water and without topsoil water-logging in Western Australia. Yields of subsequent wheat crops were largest following legume crops (40% in one season and 135% in the second compared with wheat following wheat or barley) but were also significantly greater following oilseeds. Winter wheat and sorghum grain production was higher in comparison to continual cropping of winter wheat in the southern Great Plains by limiting weed problems (Jones and Popham, 1997). In comparative grass removal methods from clover based pasture in rotational cropping sequence of canola–wheat–lupin–wheat or wheat–wheat–lupin–wheat, Harris *et al.* (2002) observed that the largest increase (80%) was by the first canola crop after winter-cleaned pasture. The yield increase by the equivalent wheat crop was 42%. Wheat grown after canola yields 11% more than wheat grown after wheat. There was 17% increase in the yield of wheat growing 3 years after canola compared with wheat growing 3 years after wheat, with wheat–lupin sequences in the intervening years for both systems and suggested that canola and lupin, both of which are non-hosts of arbuscular mycorrhizal fungi, reduced mycorrhizal root colonisation in the fourth-year wheat crop, leading to less drain on assimilates. Brendan *et al.*, (2004) have reported adverse allelopathic effects of *Brassica* on non-desirable soil organisms when rotated with cereals. These effects were additional to non-hosting of root diseases, responsible for much of the breakcrop effect observed in a following cereal crop.

In Southern Oklahoma, US, there is an abandonment of continuous wheat production due to rye grass and it has become imperative to grow canola to solve grassy weeds, disease, nematodes and some insect problems that have evolved due to continuous wheat production (Anonymous, 2002). Cropping systems in the Northern Great Plains (NGP) have evolved from wheat (*Triticum aestivum* L.) – fallow rotations to diversified cropping sequences. Consequently, weed communities have changed and in some cases, become resistant to commonly used herbicides, thus increasing the complexity of managing weeds (Derkson et al., 2002). However, more diverse cropping systems allow growers to vary the timing and modes of action of herbicides, thus delaying the evolution of herbicide-resistant biotypes (Jordan and Donaldson, 1996). Producers in the semiarid NGP have been extending and diversifying their cropping systems by including broadleaf crops such as chickpea, dry pea, lentil, canola, and mustard (Gan, *et al.*., 2003).

In southeastern US, wheat is a major winter annual crop grown in rotation with summer annual (soybean, corn, sorghum and cotton) crops. Like winter wheat, double cropping of winter canola with summer crops has the potential for increased profits, improved cash flow, and rotational benefits (Raymer *et al.*, 1990). Canola can fit as an alternative crop in rotation with summer annual crops because of similarities of life cycles and management requirements to wheat. In a region dominated by winter wheat, the acceptance and production of another crop like canola requires that it suits the cropping systems agronomically and economically and benefits the farmers. Such information on canola rotation with summer crops is not available. The objectives of this study were to: i) determine the rotational effects of summer (soybean, corn, sorghum and cotton) crops on growth and yield of winter canola and ii) evaluate the yield and economic return of double cropping of winter canola with summer crops. The selected summer crops were the ongoing regional crops used in rotation systems with winter wheat in southeastern US.

**Material and methods**

*Site characteristics*

The experiments were conducted for two crop growing seasons in Decatur silty clay loam with good drainage and high water holding capacity. The use of four opportunity cropping series permitted greater flexibility in crops to be grown, thus providing an opportunity to compare different crops: Soybean cv. Hutchinson, corn cv. Pioneer 3160, sorghum cv. Martin, RoundupReady® cotton under similar conditions. The experiment consisted of following five cropping systems:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Crop rotation</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soybean–Canola–Soybean–Canola</td>
<td>S-C</td>
</tr>
<tr>
<td>2</td>
<td>Corn–Canola–Corn–Canola</td>
<td>M-C</td>
</tr>
<tr>
<td>3</td>
<td>Sorghum–Canola–Sorghum–Canola</td>
<td>S-C</td>
</tr>
<tr>
<td>4</td>
<td>Cotton–Canola–Cotton–Canola</td>
<td>G-C</td>
</tr>
<tr>
<td>5</td>
<td>Fallow–Canola–Fallow–Canola</td>
<td>F-C</td>
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</tbody>
</table>
Experimental design

All systems were replicated four times in a randomized complete block design and each phase of each system was in place each year. The seeds of summer crops (soybean, corn, sorghum and cotton) were planted by Driller/Planter (HEGE 1000 Series, Hege Equipment Inc., Kansas) on April 11, 2002. After the harvest of these crops, canola was planted on September 28, 2002. During 2003, summer crops were planted on April 10, 2003 and canola and wheat were planted on Oct 2, 2003. Lime, N, P, and K were applied to all the above crops planted in rotations according to the soil test recommendations. Canola (cv. Jetton) was planted on a tilled seedbed with a mechanical drill/row planter at a seeding rate of 6.18 kg ha\(^{-1}\). Soybean, corn, sorghum, and RoundupReady® cotton seeds were planted at recommended seeding rate of 68, 9, 9, and 9 kg ha\(^{-1}\), respectively. The plot size for each of summer crops and canola was 1.06 m × 12.16 m adjusted to fit 6-row width of planters. Trifluralin and Sethoxydim herbicides were applied as pre- and post-emergent respectively, each at 2.1 lit ha\(^{-1}\) to control weeds.

Data collection

Data were collected on the following plant parameters during both years of the experiment: canola plant height of five randomly selected and tagged plants from each plot was measured in cm from the soil surface to the apex at physiological maturity of the crop (pods either dark yellow or dry) and results were averaged from four replications of each treatment. To compare treatment effects on plant density, final plant population counts were taken randomly from two middle rows each 2 m long selected from each plot before harvest. The total number of pods from five randomly selected plants per plot was counted at physiological maturity and the results were averaged as pods per plant. One thousand seeds from each replication were counted and weighed for seed weight determination.

The four center rows from each six-row plots were harvested by combine (HEGE 140, Hege Equipment Inc., Kansas) to determine canola seed yield. Seeds were weighed and passed through standard sieves to obtain commercially marketable seed quality. Results were adjusted to 8.5% moisture content and expressed as seed yield in kg ha\(^{-1}\).

Yield of summer crops

Soybean seed yield was determined by harvesting and threshing the plants from two middle rows each 2 m long from each plot. Results have been expressed as yield in kg ha\(^{-1}\) adjusted to 13.0 % moisture level. To obtain corn yield, data on plant population, seed yield, and ear weight was recorded. Two rows, each 2 m long were harvested for grain yield with a plot combine fitted with a two row corn head. Corn samples were collected to determine grain moisture and the crop yield has been adjusted to 15.5% moisture. Sorghum yield was determined by recording plant population, panicle yield, panicle weight, and percentage panicle heads. Two rows, each of 2 m in length were harvested for grain yield. Yield has been adjusted to 12% moisture content and expressed in kg ha\(^{-1}\). Cotton yield (lint and seed cotton) was recorded from the two middle rows, each 2 m in length of each plot and results have been expressed as yield in kg ha\(^{-1}\).

Production efficiency

The yield and economic performance of cropping systems was assessed to determine whether canola and summer crops yields were sufficient to convince farmers for practicing cropping systems. For comparing the economical values of cropping systems, the seed yields of canola and summer crops were converted into gross return. Prices of canola, soybean, corn, sorghum, cotton, and wheat were $ 23.34, 20.37, 10.71, 9.03, 95.81, and 11.34 per 100 kg in 2002-2003 and $ 24.66, 26.06, 9.25, 9.03, 102.2, and 11.38 per 100 kg in 2003-2004 respectively, as per US price index (Alabama agricultural statistics, 2004).

The percent comparison of yield parameters among canola planted after summer crops has been calculated over canola planted after fallow. All collected data were statistically analyzed using an analysis of variance (ANOVA) procedure for a randomized block design. The General Linear Model (PROC GLM) procedures of the Statistical Analysis System (SAS Inst., version 8) was used for separating means by Tukey’s test.

Results and discussions

Results

Rotational effect on canola plant height

In 2003 growing season, rotation with summer crops did not significantly influence canola plant height; however, rotational effects were significant in 2004. During 2004, canola plant height after fallow was
significantly higher than when planted after soybean (102.0 cm) but was similar (Fig. 1) when planted after corn (105.0 cm), cotton (102.9 cm), and sorghum (102.8 cm). There was significant decrease in plant height when canola was planted after soybean (4.49%) compared to canola planted after fallow (Table 1). The percentage decrease in canola plant height when planted after sorghum, cotton and corn was 3.79, 3.63, and 1.69 % respectively, when compared to canola planted after fallow.

The highest plant density due to rotation was observed in canola planted after soybean in both years (Fig. 2). Canola planted after soybean gave significantly higher plant population (40.8 and 39.5 cm in 2003 and 2004 respectively) than when planted after sorghum (33.5), cotton (33.0), and fallow (33.5) but not corn (39.0) in 2003; however, the plant counts were not significantly different among canola planted after corn, sorghum, cotton, and fallow in 2004. The percentage increase in canola density when planted after soybean and corn was 21.64% and 16.42% respectively (Table 1), over canola planted after fallow; however, final stand decreased by 1.49 % when planted after cotton in 2003. When compared to canola planted after fallow in 2004, the number of plants following soybean and corn increased by 21.54 and 15.38 % respectively, but decreased by 1.54 and 0.77 % following sorghum and cotton in 2004.

Rotational effect on pods per plant

There was no significant difference among pods per plant when canola was planted after summer crops and fallow in 2003 (Fig. 3). In contrast, the rotational differences were noticed during 2004 when canola planted after soybean produced significantly the highest pods per plant (223) than canola planted after corn (194) or cotton (192) but not when planted after sorghum (210) or fallow (211).

During 2003, the percent decrease in the pods was numerically highest in canola planted after cotton (-10.3 %) followed by soybean (-9.49%), sorghum (-6.37%), corn (-4.86%) over canola planted after fallow (Table 1). The rotational effects were observed in 2004, wherein, there was an increase in percentage of pods (5.88%) in canola planted after soybean compared to canola planted after fallow. There was a decrease in number of pods when canola was planted after cotton (-8.86%), corn (-8.2%), and sorghum (-0.66%) in comparison to pods when planted after fallow.
Canola in rotation with summer crops did not significantly effect seed weight in 2003 when planted after summer crops and fallow. However, in 2004, significantly higher seed weight was observed in canola planted after soybean (4.56), corn (4.50) and fallow (4.53) than canola planted after sorghum (4.15) and cotton (4.25). Seed weight of canola planted after cotton and sorghum did not show significant difference (Fig. 4). The percentage increase in seed weight from canola planted after soybean was 2.14 than canola planted after fallow in 2003. There was a decrease in the percentage of canola seed weight when planted after sorghum, cotton, and corn than canola planted after soybean (Table 2). In 2004, the percentage increase in canola seed weight was noticed in canola planted after soybean (0.83) than canola planted after fallow. There was a decrease in canola seed weight percentage when canola was planted after corn (-0.55), cotton (-6.08), and sorghum (-8.29) over canola planted after fallow.

### Table 2: Comparison of canola (%) for seed weight and seed yield after rotation with summer crops.

<table>
<thead>
<tr>
<th>Treatment †</th>
<th>2003</th>
<th>2004</th>
<th>% variation from FC</th>
<th>Yield (kg ha⁻¹)</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sy-C</td>
<td>2.14</td>
<td>0.83</td>
<td></td>
<td>7.12</td>
<td>8.78</td>
<td>2.12</td>
</tr>
<tr>
<td>M-C</td>
<td>-1.34</td>
<td>-0.55</td>
<td></td>
<td>0.48</td>
<td>2.12</td>
<td>2.12</td>
</tr>
<tr>
<td>S-C</td>
<td>-6.70</td>
<td>-8.29</td>
<td></td>
<td>-4.60</td>
<td>-7.86</td>
<td>-7.86</td>
</tr>
<tr>
<td>G-C</td>
<td>-6.43</td>
<td>-6.08</td>
<td></td>
<td>-4.40</td>
<td>-12.37</td>
<td>-12.37</td>
</tr>
<tr>
<td>F-C</td>
<td>-</td>
<td>-</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* *, ** Significant at the 0.05 and 0.01 probability levels, respectively; ns, non-significant.

†Sy-C, soybean-canola; M-C, corn-canola; S-C, sorghum-canola; G-C, cotton-canola; F-C, fallow-canola.
Fig. 4: Canola seed weight after rotation with summer crops.
* *, ** Significant at the 0.05 and 0.01 probability levels, respectively; ns, non-significant.
'Sy-C', soybean-canola; M-C, corn-canola; S-C, sorghum-canola; G-C, cotton-canola; F-C, fallow-canola.

Rotational effect on canola seed yield

Average growing season (Mar to June) precipitation ranged from 188.0 mm in 2003 to 56.1 mm in 2004, with temperature remaining almost the same (difference of 1.17 °C) for both the years (data not shown). Thus, the 2004 canola crop experienced less wetter than 2003 growing conditions for more branch, pod formations and seed yield in the present study.

All the yield components of canola planted after soybean, corn, sorghum, and cotton were significantly influenced by the rotation and contributed to canola seed yield in 2004; however, the data on canola plant height, pods per plant, and seed weight showed numerical differences in 2003. During 2003, the rotational effects in seed yield were significantly higher (Fig. 5) in canola planted after soybean (2739 kg ha⁻¹) than canola planted after cotton (2445 kg ha⁻¹) and sorghum (2440 kg ha⁻¹); however, the difference was non-significant to canola yield planted after soybean, corn (2569 kg ha⁻¹), and fallow (2557 kg ha⁻¹). During 2004, canola planted after soybean gave significantly higher seed yield of 3129 kg ha⁻¹ over canola planted after sorghum (2650 kg ha⁻¹) and cotton (2521 kg ha⁻¹). Canola planted after corn was not significantly different in seed yield when planted after soybean and fallow; however, it was significantly different when planted after cotton. Canola planted after sorghum gave the lowest yield, when compared with canola planted after corn, fallow, and cotton in 2003 (Table 2). The highest percentage increase was observed in canola planted after soybean (7.12%), followed by corn (0.48%) from canola planted after fallow. However, there was decrease in seed yield in canola planted after cotton (-4.40%), and sorghum (-4.60%) from canola planted after fallow. Similar decrease in seed yield was observed in canola planted after cotton (-12.37 %) and sorghum (-7.86 %) in comparison to canola planted after fallow in 2004. Canola planted after soybean and corn produced 8.78 % and 2.12 % more seed yield, respectively, than canola planted after fallow.
Economic Analysis

The financial returns varied in both the years because of variation in the prices received by the farmers as per the US price index (Alabama Agricultural Statistics, 2004). During 2003, significantly higher economic returns of $1237 and $1169 ha⁻¹ (Table 3) were observed when canola, as a double crop was planted after corn and cotton, respectively, in comparison to soybean ($996 ha⁻¹) and sorghum ($964 ha⁻¹). In 2004, the yield of canola planted after soybean, corn, sorghum, and cotton was numerically higher than the respective yields in 2003, which resulted in higher income in 2004 over 2003 and canola-cotton rotation gave highest economic returns ($1442 ha⁻¹) which was equal to soybean-canola ($1393 ha⁻¹) and was significantly higher than corn-canola ($1370 ha⁻¹) and sorghum-canola ($1084 ha⁻¹) rotation.

Table 3: Economic returns from double cropping of canola with summer crops during 2002-2004.

<table>
<thead>
<tr>
<th>Treatment†</th>
<th>2002-2003</th>
<th>2003-2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield (kg ha⁻¹)</td>
<td>Returns (US $ ha⁻¹)</td>
</tr>
<tr>
<td>Sy-C</td>
<td>1755/2739</td>
<td>357/639</td>
</tr>
<tr>
<td>M-C</td>
<td>5949/2570</td>
<td>637/600</td>
</tr>
<tr>
<td>S-C</td>
<td>4368/2440</td>
<td>394/570</td>
</tr>
<tr>
<td>G-C</td>
<td>624/2445</td>
<td>598/571</td>
</tr>
<tr>
<td>E-C</td>
<td>0/2557</td>
<td>0/707</td>
</tr>
</tbody>
</table>

*S-C, soybean-canola; M-C, corn-canola; S-C, sorghum-canola; G-C, cotton-canola; F-C, fallow-canola.
†Economic returns based on prices shown as per US price index (Alabama Agricultural Statistics, 2004).

Discussion

Canola yield plasticity varied widely indicating the importance of weather conditions in the determination of the optimum population. Rainfall during March and June of 2004 was low and maximum average temperature was higher by 1.1 °C as compared to the preceding year; as such there was higher canola seed yield among all the treatments in 2004 than in 2003 in this study.

The rotational effects during the two growing seasons on canola seed yield showed that yield as well plant density was more when canola was planted after soybean than after corn, sorghum, cotton, and fallow. Angadi et al. (2003) reported that canola adjusted seed yield across a wide range of plant density (40-80 plants m⁻²), although it did not compensate completely for the decreasing populations. They observed that the higher plant density gave higher seed yield and was stable across a wide range of plant populations, although it did not compensate completely for low populations. Reducing plant population by half from 80 to 40 plants m⁻² did not reduce seed yield when the reduced plant population was uniformly distributed, but did reduce yield when the population was non-uniformly distributed. According to Diepenbrock (2000), plant density of oilseed rape has the greatest effect on yield and the yield components of individual plants. Moreover, Grunert and Rohricht (1998) also indicated that higher plant densities achieved higher yields.

The increase in the number of pods in canola planted after soybean has been corroborated by Angadi et al. (2003) who observed that there was a strong effect of population density on the distribution of pods on the primary and secondary branches. However, the plant structure adapted to the canola planted after summer crops and fallow by increasing pods per plant at lower plant populations in this study. Angadi et al. (2002) reported that the pods formed on upper branches and the vegetative growth compete for the limited photosynthetic availability. In addition, light reflection from canola flowers reduces photosynthetic efficiency during flowering (Diepenbrock, 2000). At lower nodes, the plant can support more pods due to increased photosynthetic availability caused by increased light interception due to increased pod area.

Angadi et al. (2003) observed that seed weight in the upper portion of the canopy were similar among different population treatments. McGregor (1987) also found that seed weight was not as strongly influenced by population as were pods per plant. Early-formed pods at the top of the canopy or on the main raceme have the developmental advantage (Mendham and Salisbury, 1995) that might have masked the smaller variations in seeds per pod or seed weight. In the present study, seed weight was significantly more responsive to rotational effects when canola was planted after soybean, corn and fallow in 2004.

Seed yield of canola is a function of population density, number of pods per plant, and seed weight. However, yield structure is very plastic and adjustable across a wide range of populations. The number of pods per plant is the most responsive of all the yield components in canola (Diepenbrock, 2000) and is determined by the survival of branches, buds, flowers, and young pods rather than by the potential number of flowers and pods (McGregor, 1987). Angadi (2003) reported that seed weight was not affected by the population variation in any of the environments. Guy (1999) observed that Brassica crops such as mustard, canola, and crambe are excellent rotation crops and provide large amount of crop residue that is important for erosion control. Moreover, wheat yields were at least 25% less following wheat than after canola, mustard, crambe, or pea.
Conclusion

This study suggests that canola planted after summer crops and fallow exhibits plasticity in seed yield across a wide range of yield components though the magnitude may be different. Canola plant height was numerically more when planted after soybean than other summer crops and fallow during 2003 growing season but was significantly higher when planted after fallow and corn in 2004. Canola planted after soybean produced higher pods per plant and yield than canola planted after corn and cotton in 2004 but not in 2003. Rotation of canola after summer crops and fallow significantly influenced plant height, pods per plant, and seed weight in canola yield in the second year, however, plant height was significantly influenced by rotation during both years. Canola as a double crop provided significantly higher economic returns when planted after corn and cotton than soybean and sorghum in 2003. In 2004, canola planted after cotton gave significantly higher economic returns which were not significantly different when planted after soybean but was from corn and sorghum.

References


Alabama Agricultural Statistics., 2004. Marketing year average prices received by the farmers.


