RELAY INTERCROPPING SOYBEANS INTO WHEAT IN NON-TRADITIONAL DOUBLE-CROPPING AREAS OF KANSAS

by

STEWART R. DUNCAN

B.S., Kansas State University, 1977

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1988

Approved by:

W.T. Schapaugh

J.P. Shroyer

Major Professors

ACKNOWLEDGEMENTS

The author would like to express deep appreciation to Dr. Jim Shroyer and Dr. Bill Schapaugh for making it possible for the author to continue his education and broaden his horizons. A special thanks to Dr. Schapaugh for his advice, assistance, counselling and encouragement throughout the course of this research. A special thanks is also extended to Dr. Ray Lamond and Dr. Stan Cox for their reading and input into this thesis.

Without funding, this research may not have taken place. A special thanks is extended to the Kansas Soybean Commodity Commission for deeming this work important enough to fund. A special thanks is also extended to Mr. John Eggers and Mr. Brad Shrogren. Without their assistance, the wide range of environments to test in would not have been possible. A special thanks to my co-workers on the soybean project who shared the trials and tribulations.

Last, but definitely not least, a very special thanks to my wife and partner, Erin, and son, Amos, for seeing me through a very tough and transitional time. It was at least as hard on them as it was me. Erin's love, understanding, motivation and inspiration kept me going when the outlook was the bleakest. Amos allowed me to see the world through the eyes of a four year old which helped keep things in perspective.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

I. RELAY INTERCROPPING SOYBEANS INTO WHEAT IN NON-TRADITIONAL DOUBLE-CROPPING AREAS OF KANSAS

INTRODUCTION

Relay intercropping is the practice of growing two or more crops at the same time during different parts of each crop's life cycle. A second crop is planted into the first crop prior to its harvest. Most intercropping research to date has taken place in the tropics (Andrews and Kassam, 1976), but there has been an increase in research in more temperate climates. Research has usually involved a cereal:legume mixture (Allen and Obura, 1983; Chan et al., 1980; Chui and Shibles, 1984; Graves et al., 1980; Jeffers and Triplett, 1979; Martin and Snaydon, 1982; McBroom et al., 1981a,b; Mead and Willey, 1980; Reinbott et al., 1987; Willey and Osiru, 1972). In the upper mid-western United States the legume component has been soybean (Glycine max L. Merrill), while the cereal component has been wheat (Triticum aestivum L.), spring oats (Avena sativa L.) or barley (Hordeum vulgare L.) (Chan et al., 1980; Graves et al., 1980; Jeffers and Triplett, 1979; Jeffers, 1984; McBroom et al., 1981a,b; Reinbott et al., 1987).

Double cropping soybeans after wheat is common in the southeastern United States. This practice has been successful into the lower cornbelt, but consistently high double cropped soybean yields in the midwest are less reliable due to a shorter growing season and unreliable amounts and timeliness of rainfall (Crabtree and Rupp, 1980; McKibben and Pendleton, 1968). Approximately 75% of double-cropped soybean acres in Kansas are in the east central and southeast regions of the state. Relay intercropping may extend the northern and western limits of harvesting successful crops of wheat and soybeans in one growing season from the same land.

Moisture at establishment and early development for intercropped soybeans is critical (Chan et al., 1980; McBroom et al., 1981a), just as it is for regular full season or double-cropped soybeans. A relay intercropped system allows soybeans an additional four to six week growing season, versus a double-cropped system. Planting soybeans when wheat is in mid-boot is approximately at the onset of the period of most abundant rainfall in Kansas (Bark and Powell, 1981), which should greatly increase the probability of success.

Soybean stand establishment in growing wheat is essential for relay intercropping to become a viable cropping system. There will be competition for light, moisture and nutrients. This may lead to reduced soybean grain yields (Chan et al.,1980). When shaded at constant percentages over the soybean plants' lifetime, with greater shading, the greater seed yield reduction (Wahua and Miller, 1978). Shoots and root systems lead to interference in the interception and absorption of growth factors. The inequality of sharing these factors can lead to suppression and even death of a less vigorous component in the system.

When soil conditions are excellent, the taller components of the system will compete more effectively for light (Trenbath, 1976). A skip-row pattern allowed more light to reach soybean plants (Reinbott et al., 1987), and it should alleviate competition for other essential growth factors. Since intercrop components exploit the supplies of growth factors differently (Trenbath, 1976), and cereals have lower demands for nutrients and light as they ripen (Jensen and Federer, 1965), there is some flexibility in planting the soybean component.

Wheat cultivars may react differently to different planting patterns. Wheat does compensate for stand reduction (Darwinkel, 1984). The use of different cultivars should allow for comparison of performance and compensation with planting patterns that should minimize damage from soybean planting.

Yields of adapted and later maturing soybean cultivars were reduced less, as compared to earlier maturing cultivars, from longer periods of competition when planted as early as temperatures would allow (McBroom et al., 1981b). Indeterminate varieties yielded better than determinates in central Illinois (Chan et al., 1980). Adapted soybean cultivars should result in optimum yields.

Intercropping soybeans when wheat was at late boot stage kept wheat grain losses to a minimum (Chan et al., 1980). Wheat yields were reduced as wheat maturity increased when soybeans were intercropped (Reinbott et al., 1987). Using a planting pattern that left a skip-row for soybean rows, versus solid wheat stands, reduced wheat yields in Ohio by 10% with a 21-inch skip and none with a 28-inch skip (Jeffers and Triplett, 1979), and in Missouri, skip-row wheat yielded 16% less (Reinbott et al., 1987).

Soybean grain yields from the skip-row pattern were 82% and 89% of monocropped soybeans, while grain yields from soybeans intercropped into solid wheat were 66% of monocropped yields (Jeffers and Triplett, 1979). Double-cropped soybean yields in Missouri were 52% of monocropped soybean yields (Reinbott et al., 1987).

The objectives of this study were to: 1) examine the responses of different soybean and wheat cultivars to different planting patterns over a wide range of environments; 2) examine the compensative response of wheat in planting patterns designed to reduce wheat damage when soybeans are intercropped and 3) compare soybean performance when planted in monocropped, intercropped and double-cropped systems.

MATERIALS & METHODS

Field experiments were conducted in Kansas near Bird City and at the Ashland Research Farm, Unit 3, near Manhattan, in 1985-86. The soil at Bird City was a Keith silt loam (Aquic Arguidolls) and at Manhattan, an Eudora silt loam (Fluventic Hapludolls). In 1986-87, experiments were conducted near Bird City, near Lindsborg, near Manhattan, and at the Cornbelt Experiment Field, near Powhattan. Soils at Bird City and Manhattan were the same as the 1985-86 experiments. The soil at Lindsborg was a Hord silt loam (Cumulic Haplustolls), and the soil at Powhattan was a Grundy silty clay loam (Aquic Arguidolls).

The experimental design was a randomized, complete block with four replications. Non-double-cropped locations (Bird City, 1986 and 1987, Lindsborg, 1987, and Manhattan, 1987) had 19 treatments per replication. Each wheat cultivar was planted in eight plots; four solid and four skip-row patterns. One plot of each cultivar from each pattern was a control. In each of the other three plots of each pattern, one of three soybean cultivars was intercropped. A monocropped control plot was planted for each soybean cultivar. Experiments that included double-cropped soybean comparisons were conducted at Manhattan in 1986, and at Powhattan in 1987. These experiments had 23 plots per replication, the difference being four extra solid seeded wheat controls, two for each wheat cultivar, were added.

This allowed one double-cropped plot for each soybean cultivar following each wheat cultivar. Two semi-dwarf, stiff-strawed wheat cultivars with similar maturities and growth characteristics, Agripro 'Mustang' and Pioneer '2157'(P2157), were planted with a 10-row drill at a 10 in row spacing. To create the skip-row pattern seed from the fourth and seventh rows was diverted. Wheat was seeded at the rate of 1.2 million seeds $acre^{-1}$ of linear row, in 18 ft rows. Planting dates (Table 1) coincided with those recommended, as closely as possible. When wheat reached maturity, growth stage 11.4 on the Feekes' scale (Zadok et al., 1974), height and lodging measurements were taken, rows three through eight were trimmed to 15 ft and harvested with a Kincaid SP50 plot combine in 1986, and a Massey-Ferguson '8' plot combine in 1987. Yields were adjusted to 13% moisture content in 1987. Harvest dates are also shown in Table 1.

Three indeterminate soybean cultivars of different maturity (in parenthesis), were planted in all environments: Asgrow 'A3127' (III); 'Sherman' (III); and 'Sparks' (IV). All environments except Powhattan were irrigated. When wheat was in the boot stage, growth stage 10 on the Feekes' scale (Zadok et al., 1974), the intercrop and monocrop soybeans were planted with an Allis Chalmers 'G', two row plot planter at the rate of nine seeds ft^{-1} of row. Soybeans were seeded in 30 in. rows into solid wheat, the skip-rows in wheat, or into clean tilled seed beds in 20 ft rows. Soybean rows in solid planted wheat were outside row 1, between rows 3 and 4, 6 and 7, and 9 and 10. In the skip-row pattern, soybean rows were not in the middle of the skip, but located in the same position as those in solid wheat. Wheels and planter units were shielded so that the wheat received minimal, if any, damage. Double-cropped soybeans were planted at the rate of 9 seeds ft^{-1} into the stubble of solid wheat control plots as soon after wheat harvest as possible with a Kinze four row planter. When soybeans reached physiological maturity (Fehr and Caviness, 1977), the two center rows were trimmed to 15 ft. Soybeans were harvested with a Massey-Ferguson 8 combine. Yields were adjusted to 13% moisture. Soybean planting and harvest dates are shown in Table 1. Soybean growth stage, described by Fehr and Caviness (1977), and height were recorded at wheat harvest. Soybean maturity dates (R8) were recorded at Manhattan in 1986 and 1987, and at the Powhattan in 1987. At R8 height and lodging scores were taken on all plots. Height was measured in one of the two center rows. Lodging scores were given according to: 1 = nearly all plants erect; 2 = all plants leaning slightly; 3 = 25% to 50% plants lodged; 4 = 50% to 80% plants lodged; and 5 = more than 80% plants lodged.

The wheat received the following fertilizer. All rates of nitrogen (N) and phosphorus (P) are given in lb of actual element acre^{-1}. Starter treatments were applied at wheat planting and topdress applications were made in the spring when growth was reinitiated. Manhattan (1985-86) received 9 lb N and 23 lb P as starter and 90 lb N as topdress. Lindsborg, received 10 lb N and 47 lb P as starter and 80 lb N as topdress. At Powhattan, 18 lb of N and 46 lb of P were applied as starter and 40 lb N was topdressed. Manhattan (1986-87) and Bird City (1985-86 and 1986-87) did not receive any fertilizer.

In May, 1987, an experimental fungicide, 1-[[2(2,4-dichlorophenyl(-4-propyl-1,3-dioxolan-2-yl]methyl] 1-H-1,2, 4-triazole (propiconazole), was applied at Manhattan for control and suppression of leaf rust (Puccinia recondita f. sp. tritici), stem rust (Puccinia graminis f. sp. tritici), Septoria leaf blotch (Septoria tritici) and tan spot (Pyrenophora trichostoma). Propiconazole was applied at the rate of 1.8 oz active ingredient (a.i.) acre^{-1} at 20 lb in^{-2} in 20 gal of water with a plot sprayer.

Weeds were a problem in soybean plots during both years. Crabgrass (Digitaria sanguinalis L.), was a problem weed in the Manhattan (1986 and 1987) plots. A post-emergent grass herbicide, 2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl] - 3-hydroxy -2-cyclohexen -1-one, (sethoxydim), at the rate of 8 oz a.i. with 4 oz of Crop

Oil Concentrate (COC) in 20 gal of water acre^{-1} at 20 lb in^{-2} was broadcast once each year at Manhattan when the crabgrass reached recommended growth stage for treatment. One or more of the following, smooth pigweed (Amaranthus hybridis L.), redroot pigweed (Amaranthus retroflexus L.), common cocklebur (Xanthium pensylvanicum Wallr.) and velvetleaf (Abutilon theophrasti Medic.), were problem weeds at different experiment sites in both years. A combination of 8 oz a.i. sodium 5-[2-chloro-4-(trifluoromethyl)-phenoxy]-2-nitrobenzoate, (acifluorfen) and 12 oz a.i. 3-isopropyl-1-H-2,1,3-benzothiadiazin-4(3H)-one2,2-dioxide, (bentazon), plus 4 oz COC was applied in 20 gals of water acre^{-1} at 20 lb in^{-2} at Powhattan and Manhattan in 1986 and 1987. Weeds were also hand rogued when necessary.

Cottontail rabbits (Sylvilagus floridanus) severely defoliated most soybean plots at Manhattan in late May, 1986. Two treatments with a backpack sprayer to apply 2 oz a.i. of 15% ammonium soaps of higher soaps of fatty acids (rabbit repellent) gal^{-1}, to all of soybeans. Bean leaf beetles (Cerotoma trifurcata) infested the soybeans at Manhattan in July, 1987. Satisfactory control was achieved with the application of 1 lb a.i. 1-naphthyl N-methylcarbamate (carbaryl) in 20 gal of water acre^{-1} at 20 lb in^{-2}.

The Land Equivalent Ratio (LER), as proposed by Willey and Osiru (1972), was used to evaluate the effectiveness of intercropping. The formula for determining LER is:

$$LER = (Y_{ij}/Y_{ii}) + (Y_{ji}/Y_{jj})$$

where Y is the yield per unit area, Y_{ii} and Y_{jj} are monocrop yields of the two component crops i and j, and Y_{ij} and Y_{ji} are intercrop yields (Mead and Willey, 1980).

Data were analyzed using the General Linear Model (GLM) procedure of Statistical Analysis System (SAS) . The model for the combined analysis used locations and replications as random and all other effects as fixed. Each location from each year was considered a random environment.

RESULTS & DISCUSSION

Wheat

A wide range of cultural and environmental contrasts were responsible for wheat yields achieved at these locations (Table 2). The 1986 locations suffered from adverse environmental conditions, and were the two lowest yielding environments for the entire experiment. The Manhattan (1987) plots were inadvertently excluded from fertilization. This probably depressed yields more than any other factor. Plots at Lindsborg were damaged by low temperatures (9^{o} F) on March 29. The 1987 Bird City and Powhattan locations benefited from above normal moisture and responded with high yields.

Across all locations, solid monocropped wheat produced the highest yields (Table 2). Solid intercropped wheat yielded significantly more (P=.01) than either skip-row pattern. There was no difference in yields between skip-row monocropped or intercropped patterns. The absence of yield loss from intercropping soybeans into the 30-in., skip rows was the same as the results of Jeffers and Triplett (1979) with 28 in., skips. In solid plantings the 4.4% yield reduction from intercropping was significant at the P=.05 level, which was similar to the results of Chan et al. (1980). Skip-row monocropped wheat yielded significantly (P=.05) less (13%) than solid monocropped plots. Skip-row intercropped wheat yielded significantly less (11%) than solid intercropped plots. Skip-row intercropped wheat yields were significantly less than solid monocropped wheat yields. The yield reductions observed were less than those of 16% reported by Jeffers and Triplett (1979) in Ohio, or of 27% in Missouri (Reinbott et al., 1987). Lower plant densities in skip-rows led to lower yields. The ability of the skip-row wheat to yield 90% of solid wheat demonstrates wheat's compensative nature as reported by Darwinkel (1984).

There was a significant (P=.01) planting pattern X location interaction (Table 2). The solid pattern yields were significantly (P=.01) greater than skip-row plots at Powhattan. At Bird City (1986), Manhattan (1986 and 1987) and Lindsborg (1987), there were no significant (P=.05) differences in wheat yields with different planting patterns. The Bird City (1987) solid monocropped wheat yields were greater than yields from any other planting pattern.

Over the entire experiment, yields of P2157 were 7% higher than Mustang. Cultivars exhibited similar growth habits and agronomic characteristics and are normally expected to produce similar yields, but over these environments there was a location X cultivar interaction (Table 2). Factors that may have contributed to this interaction were severe infestations of stem and leaf rust, and differences in tolerance exhibited by the cultivars at

Manhattan in 1986. Mustang is rated as resistant to stem rust, moderately resistant to tan spot and susceptible to Septoria and leaf rust, while P2157 is rated as susceptible to stem rust, moderately resistant to leaf rust and tan spot, and resistant to Septoria (Walter, 1987). This was the only location where Mustang yielded higher than P2157. Cultivars showed no yield differences (P=.05) at Bird City in 1986, or Manhattan in 1987. At all 1987 locations, P2157 outyielded Mustang from 7% to 17%. There was no planting pattern X cultivar interaction for wheat seed yield.

Soybeans

There was more than a 50 bu acre^{-1} range in mean yields among locations (Table 2). The extremes were 15 bu. acre^{-1} at Bird City (1987) to 65.3 bu. acre^{-1} at Manhattan (1986). The 1986 Manhattan yields were 40% greater than the next highest yielding location, Manhattan in 1987. Due to diseases and low fertility, wheat offered very little competition for soybeans in the 1986 experiment at Manhattan. Mean yields at Manhattan (1987), Lindsborg and Powhattan were similar. Bird City yields in 1986 were 42% below Powhattan yields and 1987 Bird City mean yields were 29% lower than 1986 Bird City yields. The 1987 Bird City wheat crop yielded much higher than the 1986 Bird City wheat, and provided greater competition with the intercropped soybeans. The result was much lower soybean yields.

In five of the six environments, intercropped soybean yields were significantly (P=.05) less than monocropped soybeans. The only exception was observed at Manhattan (1986) where no differences among patterns were noted (Table 2). This was similar to the reported 27% losses in Missouri (Reinbott et al., 1987). Reductions were greater than those of 20% found in Ohio (Jeffers and Triplett, 1979) and 11% in Illinois (Chan et al., 1980), but less than the 43% and 48% yield losses reported in Tennessee (Graves et al., 1980) and Illinois (McBroom et al., 1981b), respectively. Reinbott et al. (1987) reported a reduction in intercropped yields due to early season (pre-wheat harvest) competition for light. Competition between wheat and seedling soybeans for essential growth factors led to reduced intercropped soybean yields. Planting soybeans into skip-row wheat resulted in a 4% yield advantage as compared to those planted into solid wheat, but this difference was not significant (P=.05), except at Lindsborg (1987) where skip-row soybeans yielded 15% more than solid intercropped soybeans.

There was no significant difference overall between cultivars (Table 2). The location X cultivar interaction for yield was due to one location, Manhattan (1986), which showed an 8% yield reduction from the highest (Asgrow A3127) to lowest (Sparks) ranked cultivar (Table 2).

Double-cropped soybeans were harvested at Manhattan (1986) and Powhattan. Monocropped soybean yields were significantly greater than intercropped or double-cropped yields (Table 2). These trends follow those found by Reinbott et al. (1987), except in Kansas, double-cropped yields were 69% of monocropped soybeans versus 52% in Missouri.

At Manhattan (1986) all treatments reached maturity before the first killing frost, while at Powhattan, double-cropped Sparks did not. At Powhattan, double-cropped soybean yields were 55% of monocropped and 79% of combined intercropped yields. This more closely resembles results from Missouri (Reinbott et al., 1987).

Jeffers et al. (1973) recommended using as late a maturing cultivar as growing season would permit for double-cropping soybeans. At Powhattan, the group IV cultivar Sparks did not mature before a killing frost when double-cropped, resulting in reduced yields. There was no significant difference in yields of A3127 or Sherman in either full-season or double-cropped patterns, but yields of Sparks were significantly (P=.05) lower in both intercropped (9%-10%) and double-cropped (30%-37%) planting patterns.

Soybean growth stage at wheat harvest was near R1, except at Bird City (1987), where many plants were at V2 stage.

All cultivars had significantly (P=.01) different heights at wheat harvest. Sparks was tallest (15.5 in.), Asgrow A3127 was next (13.7 in.) and Sherman was the shortest (12.1 in.). Soybean plants were significantly (P=.05) taller in the solid intercropped planting pattern than in the monocropped and skip-row intercropped patterns, which is similar to the findings of Reinbott et al. (1987) in Missouri. The greater the competition for light, the greater etiolation between lower nodes. The height at each location in 1987 was significantly (P=.01) different from all others: Lindsborg (16.9 in.); Powhattan (15.9 in.); Manhattan (12.2 in.) and Bird City (10.0 in.). No soybeans interfered with wheat harvest nor were they clipped by the combine. There was no significant (P=.05) difference in cultivar seed yields.

At maturity, monocropped soybeans were tallest (P=.05), skip-row intercropped and double-cropped (where planted) were next and solid intercropped were shortest (Table 3). These results were similar to those found in other research (Chan et al., 1980; Jeffers and Triplett, 1979; McBroom et al., 1981b; and Reinbott, 1986), except that Reinbott (1986) reported double-cropped soybeans as the shortest.

Sparks was significantly (P=.01) taller than either Asgrow A3127 or Sherman (Table 3). A planting pattern X cultivar interaction was due to the height of Sparks and the monocropping pattern.

Soybean height was significantly (P=.05) greater at Manhattan (1986) and Powhattan than the other environments (Table 3). Plant heights at Bird City (1986 and 1987) were not significantly different from each other, but were shorter (P=.05) than all other locations.

Planting patterns showed lodging differences (Table 4). Double-cropped soybeans lodged least followed by monocropped, skip-row intercropped and solid intercropped. This differs from the results of Chan et al. (1980) and McBroom et al. (1980b) where intercropped soybeans lodged less than monocropped. Higher lodging scores in intercropped patterns were amplified in higher yielding environments. At both low yielding Bird City environments, there was no difference in lodging among planting patterns. Etiolation at earlier stages of growth in intercropped soybeans may have led to greater lodging in higher yielding environments.

Lodging differences among cultivars were noted (Table 4). Sparks tended to lodge the most, Sherman next and Asgrow A3127 the least. Plants lodged more in higher yielding environments than in lower yielding environments. Sparks contributed heavily to this interaction.

Soybean maturity data was recorded at three locations (Table 4). Monocropped soybeans reached maturity first, skip-row intercropped soybeans were nearly three days later, solid intercropped over four days later and double-cropped matured over 17 days after monocropped soybeans. In Missouri, Reinbott (1986) found similar results. Asgrow A3127 matured nearly one day prior to Sherman and just less than four days prior to Sparks. There were planting pattern X location and the cultivar X location interactions for maturity, but no outstanding pattern exhibits itself.

Land Efficiency

The Land Equivalent Ratio (LER) (Willey and Osiru, 1972) was used to evaluate each intercropping system at each experiment. Overall, intercropping soybeans into wheat resulted in an LER value of 1.7, 70% greater production from the same acreage in solid and skip-row wheat. Double-cropping also resulted in LER's of 1.7 (Table 5). The wheat component of the system was less affected. In solid patterns there was no yield reduction due to intercropping, and only a 3% reduction in skip-row patterns. Solid intercropped wheat mean yields ranged from 86% to 105% of monocropped wheat yields . Skip-row intercropped wheat mean yields ranged from 83% to 100% of skip-row checks. Intercropped soybeans suffered slightly larger yield reductions in solid vs. skip-row wheat. Solid intercropped soybean mean yields ranged from 44% to 96% of monocropped mean yields, while skip-row mean yields ranged from 39% to 97% of monocropped mean yields. Intercropping soybeans resulted in 20% greater soybean seed yields than double-cropping. Mean double-cropped soybean yields ranged from 55% to 79% of mean monocropped soybeans.

CONCLUSIONS

Environments produced a range of wheat yields. The late spring freeze did extensive damage at Lindsborg. This location had the appearance of potential yields as high or higher than those at Powhattan and possibly Bird City (1987). The more humid climate of northeastern Kansas led to locations having much greater disease infestations than locations further west and south. Timely applications of appropriate fungicides at both Manhattan locations probably would have reduced wheat yield losses, especially in 1986.

Soybean yields also ranged widely among locations. An exceptional soybean growing season at Manhattan (1986) produced very high yields. The two northwest Kansas environments at Bird City were not able to produce acceptable intercropped soybean yields. Intercropped soybeans did yield satisfactorily at the four central and eastern Kansas locations, with no real yield differences among the 1987 locations. Intercropping soybeans into wheat does not appear to be a legitimate production option in northwest Kansas, but does merit consideration in the eastern one-half of the state.

There was no difference in soybean cultivar performance in planting patterns except that Sparks yielded significantly less when double-cropped at Powhattan, where the growing season is shorter than at Manhattan. All cultivars reached maturity when intercropped. The use of normally adapted soybean cultivar in a relay intercropping system should result in satisfactory performance.

At high yielding locations, there was a difference in wheat cultivar yields, with Pioneer 2157 outyielding Agripro Mustang, overall. Disease resistance and/or more intense management, including the use of fungicides, may reduce differences in cultivar yields. Planting pattern had no effect on yields of the different cultivars.

Leaving skip-rows in wheat reduced wheat yields 13%. Intercropping soybeans did not further reduce wheat yields.

Intercropping and double-cropping will result in reduced soybean yields as compared to monocropping. Intercropped yields were 20% greater than double-cropped. Even though monocropped and intercropped soybeans were both in growth stage R1 at wheat harvest, there was a difference in the plants. Monocropped soybeans had much more vegetative growth, more trifoliate leaves extended and more flowering nodes. Intercropped soybeans were taller, but stems were slender with fewer number of nodes with blooms and trifoliates. Skip-row soybeans lodged less, were shorter at wheat harvest, but were taller at maturity than solid intercropped soybeans. Planting in the middle of the skip might improve these desirable plant characteristics. As it was, they were in heavy competition with the wheat for light, moisture and nutrients. Unless skip-row soybeans outyielded solid intercropped enough to compensate for wheat losses from wheel traffic, there would be no preference between intercropped planting patterns.

REFERENCES

Allen, J.R., and R.K. Obura. 1983. Yield of corn, cowpea and soybean under different intercropping systems. Agronomy Journal. 75:1005-1009.

Andrews, D.J., and A.H. Kassam. 1976. The importance of multiple cropping in increasing world food supplies. In "Multiple Cropping" (R.I. Papendick, P.A. Sanchez, and G.B. Triplett, eds.), pp. 1-10. Special Publication Number 27, American Society of Agronomy, Madison, Wisconsin.

Bark, L.D., and G.M. Powell. 1981. Weather forecasts. Kansas State University Cooperative Extension Service. Bulletin L-568.

Chan, L.M., R.R. Johnson, and C.M. Brown. 1980. Relay intercropping soybeans into winter wheat and spring oats. Agronomy Journal. 72:35-39.

Chui, J.A.N., and R. Shibles. 1984. Influence of spatial arrangements of maize on performance of an associated soybean intercrop. Field Crops Research. 8:187-198.

Crabtree, R.J., and R.N. Rupp. 1980. Double and monocropped wheat and soybeans under different tillage and row spacings. Agronomy Journal. 72:445-448.

Darwinkel, A. 1984. Yield responses of winter wheat to plant removal and to wheelings. Netherlands Journal of Agricultural Science. 32:293-300.

Fehr, W.R., and C.E. Caviness. 1977. Stages of soybean development. Iowa State University Special Report 80.

Graves, C.R., T. McCutchen, L.S. Jeffery, J.R. Overton, and R.M. Hayes. 1980. Soybean-wheat cropping systems: Evaluation of planting methods, varieties, row spacings, and weed control. University of Tennessee Agricultural Experiment Station. Bulletin 597.

Jeffers, D.L., and G.B. Triplett. 1979. Management needed for relay intercropping soybeans and wheat. Ohio Report. 64(5):67-70.

Jeffers, D.L., G.B. Triplett, and J.E. Beuerlein. 1973. Management is the key to success..double-cropped soybeans. Ohio Report. 58(4):67-69.

Jensen, N.F., and W.T. Federer. 1965. Competing ability in wheat. Crop Science. 5:449-452.

Martin, M.P.L.D., and R.W. Snaydon. 1982. Intercropping barley and beans. I. Effects of planting pattern. Experimental Agriculture. 18:139-148.

McBroom, R.L., H.H. Hadley, and C.M. Brown. 1981. Performance of isogenic soybean lines in monoculture and relay intercropping environments. Crop Science. 21:669-672.

McBroom, R.L., H.H. Hadley, C.M. Brown and R.R. Johnson. 1981. Evaluation of soybean cultivars in monoculture and relay intercropping systems. Crop Science. 21:673-676.

McKibben, G.E., and J.W. Pendleton. 1968. Double-cropping in Illinois. Illinois Research. 10(3):6-7.

Mead, R., and R.W. Willey. 1980. The concept of a 'Land Equivalent Ratio' and advantages in yields from intercropping. Experimental Agriculture. 16:217-228.

Reinbott, T.M. 1986. Intercropping soybeans into standing green wheat. M.S. thesis. University of Missouri, Columbia.

Reinbott, T.M., Z.R. Helsel, D.G. Helsel, M.R. Gebhardt, and H.C. Minor. 1987. Intercropping soybean into standing green wheat. Agronomy Journal. 79:886-891.

Trenbath, B.R. 1976. Plant interactions in mixed crop communities. In "Multiple Cropping" (R.I. Papendick, P.A. Sanchez, and G.B. Triplett, eds.), pp. 129-169. Special Publication Number 27, American Society of Agronomy, Madison, Wisconsin.

Wahua, T.A.T., and D.A. Miller. 1978. Effects of shading on the N_2-fixation, yield, and plant composition of field-grown soybeans. Agronomy Journal. 70:387-392.

Walter, T.L. 1987. 1987 performance tests with winter wheat varieties. Kansas State University Agricultural Experiment Station. Report of progress 526.

Willey, R.W., and D.S.O. Osiru. 1972. Studies on mixtures of maize and beans (Phaseolus vulgaris) with particular reference to plant population. Journal of Agricultural Science. 79:517-529.

Zadok, J.C., T.T. Chang, and C.F. Konzak. 1974. A decimal code for the growth stages of cereals. EUCARPIA. Bulletin Number 7.

TABLE 1. Planting and harvest dates for wheat and soybeans in a relay intercropping experiment.

Location	Wheat		Soybeans	
	Planted	Harvested	Planted	Harvested
	date(s)			
Bird City, 1985-86	9/23	6/30	5/3	10/9
Manhattan, 1985-86†	9/26	6/18	5/1,6/25	10/13
Bird City, 1986-87	9/24	6/30	5/11	10/7
Manhattan, 1986-87	9/26	6/20	5/1	9/30
Lindsborg, 1986-87	10/17	6/22	4/29	10/6
Powhattan, 1986-87†	10/21	6/24	5/13,6/24	10/9

† Double-cropped soybeans were also planted at these locations, denoted by the two planting dates.

TABLE 2. Wheat and soybean yields summarized for planting pattern, cultivar and location in a relay intercropping study.

Location	Wheat					
	Planting Pattern				Cultivar	
	Solid Monocropped	Solid Intercropped	Skip-row Monocropped	Skip-row Intercropped	Agripro Mustang	Pioneer 2157
	bu acre^{-1}					
Bird City, 1986	28.2 a*	24.3 a	29.7 a	26.9 a	28.0 a	26.5 a
Manhattan, 1986	21.0 a	18.8 a	17.1 a	14.2 a	20.0 a	15.5 b
Bird City, 1987	62.1 a	56.4 b	55.7 b	55.6 b	55.2 b	59.8 a
Manhattan, 1987	30.4 a	28.4 a	24.6 a	24.8 a	24.6 a	29.5 a
Lindsborg, 1987	35.0 a	36.7 a	30.1 a	29.9 a	30.3 b	35.9 a
Powhattan, 1987	54.5 a	55.8 a	44.0 b	43.5 b	45.9 b	53.0 a
Mean	38.5 a	36.8 b	33.5 c	32.6 c	34.0 b	36.7 a

Location	Soybeans					
	Planting Pattern				Cultivar	
	Monocropped	Solid Intercropped	Skip-row Intercropped	Double Cropped	Asgrow A3127	Sherman	Sparks
	bu acre^{-1}						
Bird City, 1986	34.8 a	15.3 b	13.4 b		21.3 a	21.4 a	20.9 a
Manhattan, 1986	67.0 a	64.2 a	64.7 a	52.6 b	67.9 a	65.4 ab	62.6 b
Bird City, 1987	22.8 a	11.8 b	10.5 b		15.8 a	13.8 a	15.5 a
Manhattan, 1987	47.7 a	33.6 b	35.7 b		36.8 a	40.6 a	39.5 a
Lindsborg, 1987	45.5 a	29.8 c	35.2 b		37.8 a	34.4 a	38.2 a
Powhattan, 1987	45.8 a	30.6 b	33.2 b	25.1 c	37.9 a	37.5 a	34.3 a
Mean	43.9 a	30.9 b	32.1 b		36.3 a	35.5 a	35.2 a

* Mean yields for planting patterns or cultivars within a row for that crop, followed by the same letter are not significantly different at the 5% level using Fisher's LSD.

TABLE 3. Soybean plant height at maturity as affected by planting pattern X cultivar and planting pattern X location interactions in a relay intercropping study.

Planting Pattern	Cultivar: Asgrow A3127	Cultivar: Sherman	Cultivar: Sparks	Location: Manhattan 1986	Location: Bird City 1986	Location: Manhattan 1987	Location: Bird City 1987	Location: Lindsborg 1987	Location: Powhattan 1987
	inches								
Monocropped Solid	28 a*	29 a	35 a	33 a	25 a	28 a	26 a	33 a	38 a
Intercropped Skip-row	23 b	22 b	24 c	28 c	18 b	24 a	19 b	23 b	25 c
Intercropped Double-Cropped	24 b	23 b	25 b	30 b	16 b	24 a	18 b	26 b	30 b
Cropped				31 b					29 b

* Means of cultivars or locations within a column, followed by the same letter are not significantly different at the 5% level using Fisher's LSD.

TABLE 4. Soybean plant lodging and maturity summarized for the main effects planting pattern, cultivar and location in a relay intercropping study.

	Planting Pattern				Cultivar		
Location	Monocropped	Solid Intercropped	Skip-row Intercropped	Double Cropped	Asgrow A3127	Sherman	Sparks
			lodging score†				
Bird City, 1986	1.2 a*	1.1 a	1.0 a		1.0 a	1.0 a	1.3 a
Manhattan, 1986	2.5 b	3.4 c	3.3 c	1.8 a	2.4 a	3.3 b	3.6 c
Bird City, 1987	1.1 a	1.0 a	1.0 a		1.0 a	1.0 a	1.2 a
Manhattan, 1987	1.0 a	1.5 b	1.3 ab		1.1 a	1.1 a	1.6 b
Lindsborg, 1987	1.6 a	2.0 ab	2.2 b		1.6 a	1.9 ab	2.2 b
Powhattan, 1987	1.8 ab	2.6 b	2.0 ab	1.5 a	1.9 a	2.0 ab	2.5 b
			maturity date‡				
Manhattan, 1986	20 a*	21 b	21 b	38 c	21 b	18 a	23 c
Manhattan, 1987	16 a	21 b	20 b		16 a	20 b	21 b
Powhattan, 1987	22 a	28 b	27 b	39 c	24 a	24 a	28 b

* Means of planting patterns or cultivars within a row for that particular parameter, followed by the same letter are not significantly different at the 5% level using Fisher's LSD.

† 1 = nearly all plants erect; 2 = all plants leaning slightly; 3 = 25% to 50% plants lodged; 4 = 50% to 80% plants lodged; and 5 = more than 80% plants lodged.

‡ Maturity dates are the number of days after August 31 until 95% of the pods turn mature color.

Table 5. Land Equivalent Ratios in a relay intercropping study.

Planting Pattern	Location					
	Manhattan 1986	Bird City 1986	Manhattan 1987	Bird City 1987	Lindsborg 1987	Powhattan 1987
Solid Intercropped	1.86	1.3	1.63	1.43	1.71	1.69
Skip-row Intercropped	1.8	1.3	1.75	1.46	1.77	1.71
Double-Cropped	1.79					1.55

II. EVALUATION OF TRACTOR WHEEL AND PLANTER UNIT TRAFFIC ON WHEAT YIELD IN A RELAY INTERCROPPING SYSTEM

INTRODUCTION

Relay intercropping soybeans (Glycine max L. Merrill) into wheat (Triticum aestivum L.) with conventional planting methods, will result in wheat being run over by the tractor tires and planter units. Tractor tire damage to wheat is similar to that which occurs in intensively managed wheat, where various treatments are performed with tractors. Damage from planter units to wheat is another facet which should be considered.

The earlier wheat is run over, the less chance for significant yield reductions. No significant reduction in yield resulted when wheat rows were run over at an early growth stage (Zadok et al., 1974), 3 - 4 on the Feekes' scale (Olvang and Johnsson, 1983). Chan et al. (1980) reported that intercropping at the late boot stage (10) kept wheat grain losses at a minimum. In Missouri, as wheat plant maturity increased, yields decreased when soybeans were intercropped (Reinbott et al., 1987). There is a compensative reaction in the rows bordering those run over, the earlier in the life-cycle that this occurs. Darwinkel (1984) found the yield compensation of rows bordering those wheeled was up to 78%, depending on number of times the rows were run over. Darwinkel (1984) also found that leaving the rows empty for the tractor tires (tram lines), resulted in up to 89% compensation in yield by the border rows. In Ohio, Jeffers and Triplett (1979) found no reduction in wheat yields when a skip-row was removed every 28 in., for planter units, but Reinbott et al. (1987) reported a 16% yield reduction with skip-rows in Missouri. Reinbott (1986) found that border rows to the wheel track showed no yield compensation, so wheat yield reduction was the result of mechanical damage from the coulters and openers of the drill used to plant soybeans.

The objectives of this study were to: 1) examine the response of wheat in planting patterns that allowed for different amounts of traffic from tractor wheels and soybean planter units; and 2) to evaluate soybean performance in these planting patterns using different planter units.

MATERIALS & METHODS

The experiment was conducted in 1986-87, at the Ashland Research Farm, Unit 3, near Manhattan, Kansas and the Cornbelt Experiment Field near Powhattan, Kansas. The soil at Manhattan was a Eudora silt loam (Fluventic Hapludolls) and at Powhattan, a Grundy silty clay loam (Aquic Arguidolls).

The experimental design was a randomized complete block with four replications. Ten treatment combinations (Table 1) were evaluated. There were 10, 10-in., wide 20 ft long wheat rows plot^{-1}. Three treatments had seed diverted so that rows two and eight were left blank to form a skip-row for tractor wheel traffic. This resulted in 17% less harvestable area in these plots. There were four monocropped wheat treatments: three solid, with 10 rows of wheat and one skip-row. At soybean planting, an International Harvestor 574 (IH) tractor was driven over rows two and eight in one solid plot and over rows two, three, eight and nine in another, resulting in 17% and 33%, respectively less harvestable plot area. Soybeans were intercropped in the other six treatments. Soybeans were planted with either an Allis-Chalmers 'G' (AC) plot planter or with a Kinze four row planter. Wheels and planter units on the AC were shielded to minimize mechanical damage to the wheat. The double-disc furrow openers on the Kinze were raised out of the ground when intercropping, and deflected the wheat rows around the main planter units. Press wheels on the Kinze were 9 in., wide and would fit between the 10 in., wheat rows if the tractor and planter were perfectly aligned. The soybean rows were located outside of row one, and between rows three and four, six and seven, and nine and ten. There were four patterns intercropped with the AC, three into solid wheat and one into skip-row wheat. One of the solid patterns had no additional traffic. The IH tractor was used to run over rows two and eight in one intercropped plot, and over rows two, three, eight and nine in another. The tractor and Kinze planter were used to intercrop in one skip-row and one solid wheat pattern. In the skip-row pattern, the tractor wheels travelled in the skips. In the solid wheat tractor wheels ran over rows two, three, eight and nine.

Agripro 'Victory', a semi-dwarf, stiff-strawed wheat was planted at both locations. The wheat was planted with a 10-row drill in 10 in. row spacings at the rate of 1.2 million seeds acre^{-1} of linear row, in 18 ft rows. Planting dates were November 6, 1986, at Manhattan, and October 21 at Powhattan. When wheat reached growth stage 11.4, plant height was measured and rows three through eight were trimmed to 15 ft. Wheat was harvested with a Massey-Ferguson '8' plot combine. Yields were adjusted to 13% moisture content. Wheat harvest dates were June 20, 1987, at Manhattan and June 24 at Powhattan.

One indeterminate soybean cultivar, Asgrow 'A3127', was used in this experiment. The soybeans were intercropped when the wheat was at growth stage 10.4. Soybean planting dates were May 13, 1987, at Powhattan and May 14 at Manhattan. This is later than what is considered optimum to minimize damage to wheat (stage 10), but an early season favored wheat, and the crop advanced more rapidly than anticipated. Soybeans were seeded at the rate of 9 seeds ft^{-1} of row in 30 in., rows that were 20 ft in length. When soybeans reached physiological maturity, the two center rows were trimmed to 15 ft. Soybeans were harvested at maturity with the Massey-Ferguson combine and yields were adjusted to 13% moisture. Harvest dates were September 30, 1987 at Manhattan and October 9 at Powhattan. Soybean growth stage and plant height were recorded at wheat harvest. Height and lodging scores were recorded at soybean harvest.

At Manhattan, 50 lb $acre^{-1}$ actual nitrogen (N) was top-dressed on April 25, due to inadvertent omission earlier in the season. Starter fertilizer was applied pre-plant at the rate of 18 lb $acre^{-1}$ actual N and 46 lb $acre^{-1}$ actual phosphorus at Powhattan. When wheat began spring growth an additional 40 lb $acre^{-1}$ actual N was applied.

Weeds were a problem in soybeans at both locations. Smooth pigweed (_Amaranthus hybridis_ L.), redroot pigweed (_Amaranthus retroflexus_ L.), velvetleaf (_Abutilon_ theophrasti Medic.) and crabgrass (Digitaria sanguinalis [L.] Skop.) infested the Manhattan site. A post-emergent grass herbicide, 2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio) propyl]-3-hydroxy-2-cyclohexen-1-one (sethoxydim), was spot treated at the rate of 8 oz active ingredient (a.i.) plus 4 oz Crop Oil Concentrate (COC) in 20 gal of water acre^{-1} at 20 lb in^{-2}, to control crabgrass. A combination of 8 oz a.i. sodium 5-[2-chloro-4-(trifluoromethyl) phenoxy] - 2-nitrobenzoate (acifluorfen) and 12 oz a.i. 3-isopropyl-1-H-2,1,3- benzothiadiazin-4(3H)-one2,2-dioxide (bentazon), plus 4 oz COC in 20 gal of water acre^{-1} at 20 lb in^{-2} was broadcast to control the broadleaf weeds. At Powhattan, the same broadleaf weed control treatment was broadcast to control redroot pigweed, velvetleaf and common cocklebur (Xanthium pensylvanicum Wallr.) in the plots. Weeds were also hand rogued when necessary.

Bean leaf beetles (Cerotoma trifurcata) infested Manhattan in July. They were satisfactorily controlled with an application of 1 lb a.i. 1-naphthyl N-methylcarbamate (carbaryl) in 20 gal of water acre^{-1} at 20 lb in^{-2}.

Data were analyzed with the General Linear Model (GLM) procedure of Statistical Analysis System (SAS). GLM was used due to the loss of the first replication at Manhattan. Locations and replications were used as random variables, while all other effects were fixed.

RESULTS & DISCUSSION

Wheat

Location and planting pattern had significant (P=.05) effects on wheat yields (Table 2). Where planters used to intercrop soybeans into the wheat could be compared, there was no difference between wheat yields and there was no location X planting pattern interaction.

The mean wheat yield at Manhattan was lower (28%) than that at Powhattan. The Manhattan site was planted in October, but water stood on the site as the result of heavy rains and over 50% of the plots were destroyed. Wheat was replanted in early November. Another contributing factor to the lower wheat yields was that the wheat received no fertilization until late April, when nitrogen was topdressed. Powhattan yields reflected excellent growing conditions.

There were no differences between wheat yields from planting patterns of solid monocropped and solid wheat intercropped with the AC planter (Table 2). Treatments with two harvestable rows run over, 33% of the plot area, generally had the lowest yields, although they were not always statistically lower. Overall, intercropping soybeans into solid wheat with the AC reduced wheat yields 0.2 bu acre^{-1} when compared to solid monocropped wheat. Yields from these two patterns were significantly greater than the solid monocropped pattern with two wheat rows wheeled. Reducing the harvested plot area 17%, by skip-row monocropping and wheeling one row of wheat that was intercropped with the AC, lowered wheat yields 11% and 13%, respectively from solid monocropped yields. These results are similar to those of Reinbott et al. (1987). Although yields from these treatments had 10 bu $acre^{-1}$ differences in mean yields, they were not statistically different from any other treatment. Wheeling one row of wheat reduced yields 20%.

The patterns compared to assess tractor wheel and planter unit damage to wheat were the skip-row intercropped and solid intercropped with two rows wheeled. Even though intercropping generally reduced yields, there were no significant differences in wheat yields from the two planters used to intercrop the soybeans (Table 2). When comparing skip-row intercropped, and intercropped plots with two rows wheeled, yields at Manhattan were 26% less than those at Powhattan. In the AC planted plots, the only damage done to the wheat was in those rows that the tractor was driven over. The Kinze planter damaged wheat when used to intercrop soybeans, even though wheat rows were on 10 in., centers and press wheels were 9 in., wide. Wheat was at growth stage 10.4 at both locations, well past the optimum stage (10.0) for intercropping. When run over, wheat did not recover enough to be combine harvested. This indicates that the tractor tires, not the planter units, were responsible for wheat yield reductions in this intercropped system.

Wheat was 9.2 inches shorter at Manhattan than at Powhattan. The shorter growing season in the fall, due to replanting, and especially the lack of supplied nutrients certainly were contributing factors. Planting pattern had no effect on wheat height.

Soybeans

There was only one significant difference between yields of all treatments and that was when soybeans were intercropped into solid vs. skip-row wheat with the AC planter (Table 2). Harvestable soybean rows in the skip-row wheat pattern were both adjacent to a wheat row that was bordering the skip. Wheat in those border rows may have competed more aggressively for growth factors, resulting in lower soybean yields. Soybean yields at Manhattan were 35% greater than those at Powhattan. The ability to irrigate at Manhattan provided needed water inputs at critical times during crop development.

When planter effects could be compared, there was no significant mean yield reduction. The only effect significantly influencing soybean yields was location, where Powhattan mean soybean yields were only 65% of those at Manhattan, the same as the overall location trend.

Soybean growth stage was recorded at wheat harvest, and both treatment and location, influenced the development of the seedling soybeans (Table 3). All of the Powhattan soybeans were at the R1 stage at wheat harvest. At Manhattan, all soybeans intercropped with the AC and having less than two rows run over, were also at R1, but those planted with the Kinze and/or with two rows wheeled were slightly retarded in development (Table 3).

At wheat harvest soybeans at Powhattan were 6.5 inches taller than those at Manhattan. The wheat canopy was much denser at Powhattan, possibly leading to greater etiolation of the lower nodes.

At maturity, soybeans intercropped into solid wheat tended to be taller than soybeans in skip-row wheat (Table 3). Soybeans were not planted in the skip rows, but were adjacent to a skip-row border row on one side. Since there was no difference in height before wheat harvest, it is difficult to draw a conclusion from this effect. The soybeans at Powhattan were significantly taller at wheat harvest and remained so throughout the growing season to harvest. Manhattan soybeans grew more after wheat harvest, but were still shorter at maturity than those at Powhattan.

Soybean lodging scores were significantly different across locations (Table 3). The mean soybean lodging score at Manhattan, 1.7, was lower than that at Powhattan, 2.1. The etiolation at lower nodes may have led to plants that were weaker at the base and therefore more prone to lodging at Powhattan.

CONCLUSIONS

Leaving a skip-row in wheat for tractor wheels to pass through lowered harvestable wheat area 17%, but yields only 11%. Intercropping soybeans into this pattern lowered wheat yields 2.5 bu acre^{-1}, for a total of 17% below solid monocropped wheat. Running over two wheat rows with the tractor and pulling a planter reduced harvestable wheat area 33%, but yields by only 27%, to 34.25 bu acre^{-1}. Some of the yield loss was due to the advanced stage of wheat growth when the intercropping operation was performed. Many plants were flattened due to the treatment and never came back up, so were not harvested. Darwinkel (1984) reported that the later wheat was run over in its growth cycle, the less the rows bordering those that were wheeled would compensate in yield. When just one row was run over and the AC planter was used, wheat losses were only 13%, less than half of the wheat yield losses in plots where two rows were wheeled, nearly 7 bu acre^{-1} extra return. Since soybean yields were not affected by planting pattern, it should be the goal to minimize wheat damage to maximize returns.

This experiment was set up so that the damage to wheat would be as much as or more than a farmer would expect. The four row planter in our operation would allow for more tractor wheelings per acre than the six-row and eight-row units commonly used in this area of Kansas.

REFERENCES

Darwinkel, A. 1984. Yield responses of winter wheat to plant removal and to wheelings. Netherlands Journal of Agricultural Science. 32:293-300.

Fehr, W.R., and C.E. Caviness. 1977. Stages of soybean development. Iowa State University. Special Report 80.

Jeffers, D.L., and G.B. Triplett. 1979. Management needed for relay intercropping soybeans and wheat. Ohio Report. 64(5):67-70.

Olvang, H., and L. Johnsson. 1982. Track experiments in wheat. Field Crop Abstracts. 35(10):791.

Reinbott, T.M., Z.R. Helsel, D.G. Helsel, M.R. Gebhardt, and H.C. Minor. 1987. Intercropping soybean into standing green wheat. Agronomy Journal. 79:886-891.

Zadok,J.C., Chang, T.T., and C.F. Konzak. 1974. A decimal code for the growth stages of cereals. EUCARPIA. Bulletin Number 7.

TABLE 1. Planting patterns and treatments in a wheel traffic study.

Treatment †	
S	Monocropped wheat.
SR	Skip-row monocropped wheat. One out of six rows left blank.
S/1	Monocropped wheat. One out of six rows driven over using a tractor.
SI/AC	Wheat with soybeans intercropped with the Allis-Chalmers 'G' plot planter.
SI/1/AC	Wheat with soybeans intercropped with the AC. One out of six rows driven over using a tractor.
S/2	Monocropped wheat. Two out of six rows driven over using a tractor.
SI/2/AC	Wheat with soybeans intercropped with the AC. Two out of six rows driven over using a tractor.
SI/2/KN	Wheat with soybeans intercropped with the Kinze planter. Two of six rows driven over using a tractor.
SRI/AC	Skip-row wheat with soybeans intercropped with the AC plot planter.
SRI/KN	Skip-row wheat with soybeans intercropped with the KN planter. Tractor tires traveled in the skips.

† All wheat plots were planted with a 10-row drill having 10 in., row spacings in 20 ft rows. Rows three through eight were harvested. All soybean plots consisted of four, 20 ft rows on 30 in., centers. Rows two and three were harvested. Rows were located, relative to wheat rows, outside row one, and between rows three and four, six and seven, and nine and ten.

TABLE 2. Wheat and soybean yields summarized for the main effects treatment and location, and for soybean planter used in a wheel traffic study.

Wheat Treatment	Location: Manhattan	Location: Powhattan	Mean
	bu acre^{-1}		
S	42.4 a*	52.0 a	47.2 a
SR	36.2 ab	47.5 a	41.8 ab
SI/AC	37.4 ab	56.6 a	47.0 a
S/1	29.5 ab	46.4 a	37.9 ab
SI/1/AC	33.0 ab	49.2 a	41.1 ab
S/2	25.7 b	38.0 b	31.8 b
SI/2/AC	28.6 ab	38.8 ab	33.7 ab
SI/2/KN	31.8 ab	37.7 b	34.8 ab
SRI/AC	32.1 ab	46.4 a	39.2 ab
SRI/KN	32.7 ab	45.6 ab	39.1 ab
Mean	32.9 b	45.8 a	39.9

Soybean Planter	Mean
	bu acre^{-1}
AC	36.3 a
KN	36.0 a

Soybean Treatment	Location: Manhattan	Location: Powhattan	Mean
	bu acre^{-1}		
SI/AC	50.3 a	30.9 a	40.6 a
SI/1/AC	46.0 ab	27.8 a	36.9 ab
SI/2/AC	45.7 ab	30.2 a	38.0 ab
SI/2/KN	45.5 ab	31.6 a	38.6 ab
SRI/AC	41.7 b	27.8 a	34.7 b
SRI/KN	42.2 b	28.8 a	35.5 ab
Mean	45.2 a	29.5 b	36.7

Soybean Planter	Mean
	bu acre^{-1}
AC	36.3 a
KN	37.6 a

* Means within the same column, followed by the same letter for that crop are not significantly different at the 5% level using Fisher's LSD.

TABLE 3. Soybean height and growth stage† at wheat harvest, and soybean mature height and lodging‡ summarized for the main effects planting pattern and location in a wheel traffic study.

	Location							
	Manhattan				Powhattan			
	Wheat Harvest		Mature		Wheat Harvest		Mature	
Planting Pattern	height	stage	height	lodging	height	stage	height	lodging
	inches		inches		inches		inches	
SI/AC	8 a*	4.0 a	25 ab	1.7 ab	15 ab	4.0 a	28 a	2.5 a
SI/1/AC	8 a	4.0 a	26 ab	1.7 ab	16 a	4.0 a	27 ab	2.0 a
SI/2/AC	8 a	3.3 b	26 ab	2.4 b	14 b	4.0 a	28 a	2.0 a
SI/2/KN	8 a	3.5 b	26 ab	1.9 b	15 ab	4.0 a	27 ab	2.0 a
SRI/KN	7 a	3.3 b	25 ab	1.7 ab	14 b	4.0 a	25 b	2.0 a
SRI/AC	9 a	4.0 a	23 b	1.0 a	15 ab	4.0 a	26 ab	2.0 a

* Means within a column, followed by the same letter are not significantly different at the 5% level using Fisher's LSD.

† Soybean growth stages as defined by Fehr and Caviness (1977) were assigned numerical values: 1 = V2; 2 = V3; 3 = V6; and 4 = R1.

‡ Soybean lodging scores: 1 = nearly all plants erect; 2 = all plants leaning slightly; 3 = 25% to 50% plants down; 4 = 50% to 80% plants down; 5 = over 80% plants down.

RELAY INTERCROPPING SOYBEANS INTO WHEAT IN NON-TRADITIONAL DOUBLE-CROPPING AREAS OF KANSAS

by

STEWART R. DUNCAN

B.S., Kansas State University, 1977

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1988

ABSTRACT

Research was conducted to evaluate the productivity relay intercropping soybeans (Glycine max L. Merrill) i winter wheat (Triticum aestivum L.) in areas of K where the length of the growing season and inade rainfall limit the productivity of conventional double-cropped soybeans. The range of adaptability of relay intercropping, the ability of wheat and soybeans to perform in different planting patterns, and whether or not a soybean or wheat cultivar X planting pattern interaction existed, were the primary points of interest. Winter wheat was planted in solid and skip-row patterns at six environments in northern and western Kansas in 1985 and 1986. Full season soybeans were planted alone or intercropped into the wheat when the wheat reached the late boot stage. Double-cropped soybeans were planted for comparison at two of the environments. Two wheat cultivars, 'Agripro Mustang' and 'Pioneer 2157', and three soybean cultivars, 'Sparks', 'Sherman', and 'Asgrow A3127' were used. Wheat yields in skip-row patterns were 13% lower than those in solid patterns. Intercropping soybeans into wheat did not reduce wheat yields. Pioneer 2157 wheat yielded 7% more than Agripro Mustang. Intercropped soybeans yielded 28% less than monocropped, but 20% more than double-cropped soybeans. There was no difference between soybean yields from soybean cultivars or the

intercropped patterns. There was no soybean cultivar X planting pattern interaction. Biological productivity, as measured by the Land Equivalent Ratio, was increased with relay intercropped vs. double-cropped soybeans. Relay intercropping resulted in 6.5% lower wheat yields than double-cropped systems, but it made up for this with 9.5% higher soybean yields. Relay intercropping has the potential to increase returns above double-cropping without some of the risks involved in non-traditional double-cropping areas of Kansas. Relay intercropping did not appear to be a production option in far western Kansas where the soybeans were unable to compete effectively with the wheat for available critical growth factors. Research was also conducted to evaluate the effect of tractor wheel traffic and planter units on the productivity of wheat and soybeans in a relay intercropping system. Soybean yields from plots established with two different planters were also compared. Winter wheat, cultivar 'Agripro Victory', was planted in solid and skip-row patterns at two environments in northeast Kansas in 1986. The skip-rows were entirely for tractor wheel traffic. Two different planters were used to intercrop soybeans, cultivar Asgrow A3127, when wheat reached the late boot stage in 1987. One planter was a regular four-row planter mounted on a tractor. The other planter was a modified plot planter designed to minimize mechanical damage to the wheat. A tractor was driven over zero, one or two harvestable wheat rows in those plots planted with the modified planter. Two harvestable wheat rows were run over by the tractor when the four row planter was used to intercrop soybeans. There were differences in wheat yields due to environment and planting pattern. Skip-row pattern wheat yields were 15% lower than those of solid monocropped wheat. Running over one or two rows of wheat with the tractor rather than leaving skip-rows reduced yields 16% and 29%, respectively. Planter units did not increase wheat yield reductions over those incurred by the tractor wheels. There was no difference in wheat yield reductions from either soybean planter. Soybean yields were different between environments and planting patterns.

Additional index words: Glycine max L. Merrill, Triticum aestivum L., Soybeans, Wheat, Relay intercropping, Double-cropping, Compensation, Skip-row, Planting patterns, Spatial arrangements, Wheeling, Traffic.