Management strategies for double –crop soybean planted after wheat

Summary

Double-crop (DC) soybeans (*Glycine Max* L.) are gaining popularity as an alternative system to intensify productivity without expanding the farming area and can potentially increase net-return. However, the DC soybean system faces many challenges such as late planting, that decreases yield potential. A study was conducted in 4 site-years in Ashland, KS, during the 2016 and 2017 growing seasons. In both years, the soybean variety planted was Asgrow 4232 (MG 4.2). The soybean was planted right after two different wheat harvest timings (Study 1, early-wheat harvest 18–20%; and Study 2, conventional-harvest 13–14%). Seven treatments were evaluated in each of the soybean planting dates: 1) common practice; 2) no seed treatment (without seed fungicide+ insecticide treatment); 3) non-stay green (without foliar fungicide + insecticide application); 4) high seeding rate (180,000 seeds/a); 5) wide rows (30-inch row-spacing); 6) nitrogen (N) fixation (without late-fertilizer N application); and 7) kitchen sink (includes all management practices. There was adequate precipitation distribution in 2016, which helped to nurture the soybean plants even when planting later in the season. In 2017, precipitation was not well distributed, and the early planting date was affected by low precipitation record during early season. In overall, the high plant population and the kitchen sink treatments presented maximum yields; while the common practice scenario showed the lowest yields.

Keywords soybean, improve yield, intensive management

Introduction

Sustainable intensification of agricultural systems need to be better studied and practiced, with the objective of increasing food production to meet the global population’s needs. Although challenging, the goal of increasing soybean yields is possible with new and innovative technologies and cropping systems, improved production methods and effective educational/technology transfer programs. Double-cropping (DC) soybean after small grains addresses world food demand by growing two crops in one year and simultaneously addresses environmental concerns by growing a harvestable "cover crop" and minimizing the cost of summer weed control where there is no direct return on their investment. Also, with declining commodity prices of wheat, producers are seeking other avenues to increase the productivity of their land and increase net-return from their farm. Soybean can be managed in no-till (NT) systems, reducing costs due to less machinery, fuel and labor expenses after the wheat harvest. Furthermore, NT maintains wheat residue on soil surface which prevents excessive runoff of nutrients and other chemicals and enhancing good soil properties. Double-crop soybean area increased by 28% from 1988 to 2012 in US (Seifert and Lobell, 2015). The total DC area was projected to be 1.8 million hectares, representing 5% of the soybean planted area in the US (USDA – NASS, 2018). However, the yield gap between full-season and double-crop soybeans is large, with the risk of crop failure due to heat and drought during the late summer. To improve yields for DC soybean there

are some management practices that should be further investigated: 1) fertilizer application, promoting stronger plant growth and earlier canopy closure to overcome stresses due to a late planting season; 2) ideal row spacing and seeding rate, allowing more plants in the same unit area, potentially suppressing weed establishment and increasing yield; 3) integrated pest management, due to the late planting, the risk of late summer soil and foliar disease and insects could decrease yield; and 4) earlier planting time to lengthen growing season and allow more time for soybean plants to set pods and seed before the first killing frost.
The objective of this study was to improve yields and profitability of soybeans grown in double crop systems without sacrificing wheat yield or profitability and identify the main yield-limiting factors affecting crop productivity.

Procedures

The soil type at the Ottawa location was a Woodson silt loam (Mollisols) and at Ashland Bottoms location it was a Belvue Silt Loam. Soil samples were taken prior to planting at a depth of 0 to 6 in. Soil chemical parameters analyzed were pH, Mehlich P, cation exchange capacity (CEC), organic matter (OM), calcium, magnesium, and potassium (K) availability (Table 1).

Table 1. Pre-plant soil characterization at 0-to-6-in. depth at Ashland, KS, for 2016 and 2017.

Soil parameters	Ashland 2016	Ashland 2017
pH	5.9	6.1
Mehlich P (ppm)	57.7	62.5
CEC (meq/100 g)	7	9.4
Organic matter (%)	1.1	1.5
Potassium (ppm)	223.0	206.3
Calcium (ppm)	1028.8	1061.1
Magnesium (ppm)	105.8	118.3

The studies were arranged in a randomized complete block design with 4 replications. Plot size was 10-ft wide × 60-ft long. The soybean variety utilized was Asgrow 4232, maturity group 4.2. Soybean was planted immediately after wheat harvest of the cultivar WB Cedar. In each year, there were two experiments with two different planting dates (based on early and late wheat harvest). Early planting was on June 10th, 2016, and June 13th, 2017, and late planting was on June 23rd, 2016, and June 22nd, 2017. Seven treatments were evaluated: 1) common practice, CP; 2) no seed treatment, NST; 3) non-stay green, NSG; 4) high plant population (180,000 seeds/a), HP; 5) wide rows, WR (30-in.); 6) N fixation, NF (without late-season fertilizer N); and 7) kitchen sink, KS. The specific management practice included for each treatment is listed in Table 2.

Table 2. Management practices for treatments imposed on double-crop soybean planted after wheat for the early- and late-planting studies at Ashland, KS, in 2016 and 2017.

Treatment	Description	Seed treatment	Fungicide / insecticide	Fertility	Population	Rows	Late nitrogen
1	Common practice	No	No	No	140K	30	No
2	No seed treatment	No	Yes	Yes	140K	15	Yes
3	Non-stay green	Yes	No	Yes	140K	15	Yes
4	High population (180K)	Yes	Yes	Yes	180K	15	Yes
5	Wide rows	Yes	Yes	Yes	140K	30	Yes
6	Nitrogen fixation	Yes	Yes	Yes	140K	15	No
7	Kitchen sink	Yes	Yes	Yes	140K	15	Yes

The seed treatment was Acceleron Standard (Monsanto Company) which contains a fungicide + insecticide. For the foliar fungicide + insecticide application, the chemicals used were Aproach Prima + Prevathon (6 + 17 fl oz/a) and applied to soybean at the R3-R4 growth stage. Herbicides and hand weeding were used to maintain no weed interference for the entire season. Fertilizer application was performed on treatments 2 to 7 using the formulation 7-7-7-7S-7Cl (chloride). The application rate was 10.93 lb/a of N, phosphorus (P), K, S and Cl. In treatment 2 to 6, late N was applied at a rate of 51 lb/a, in the formulation of 32-0-0 (N-P-K). Biomass was collected in a 12.5 ft2 area, sampled outside the area collected for yield.

Results

Yield and Biomass

The year of 2016 presented adequate precipitation distribution and quantity. Due to that, there were no significant effect when comparing yield responses to management treatments (Figure 1). In 2017, precipitation distribution was not ideal for early planting. There was no rain between early and late planting, and for that reason, the experiment that was planted later, presented an advantage in relation to uniform emergence.

For all the experiments, except for the early planting in 2017, the high plant population treatment showed a trend of greater yields, along with the kitchen sink treatment, relative to the other treatments evaluated in this study.

Biomass accumulation was greater in 2016 for both planting dates when compared to 2017 (Figure 2). However, there were no significant effects for difference among planting dates or treatments, for biomass accumulation.

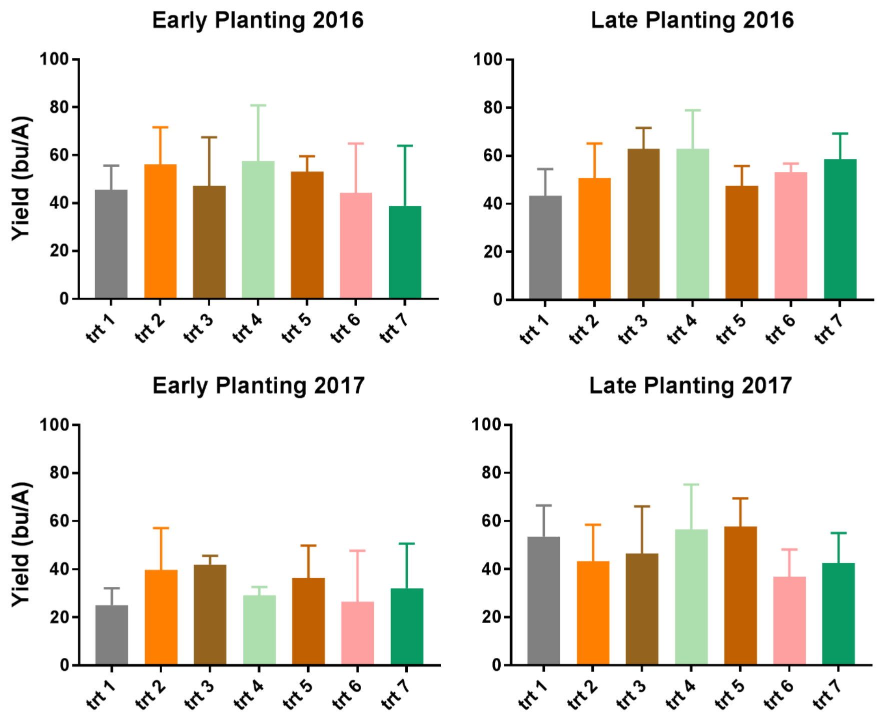

Figure 1. Grain yield for double-crop soybean, when planted early and late at Ashland Bottoms, KS, for 2016 and 2017.

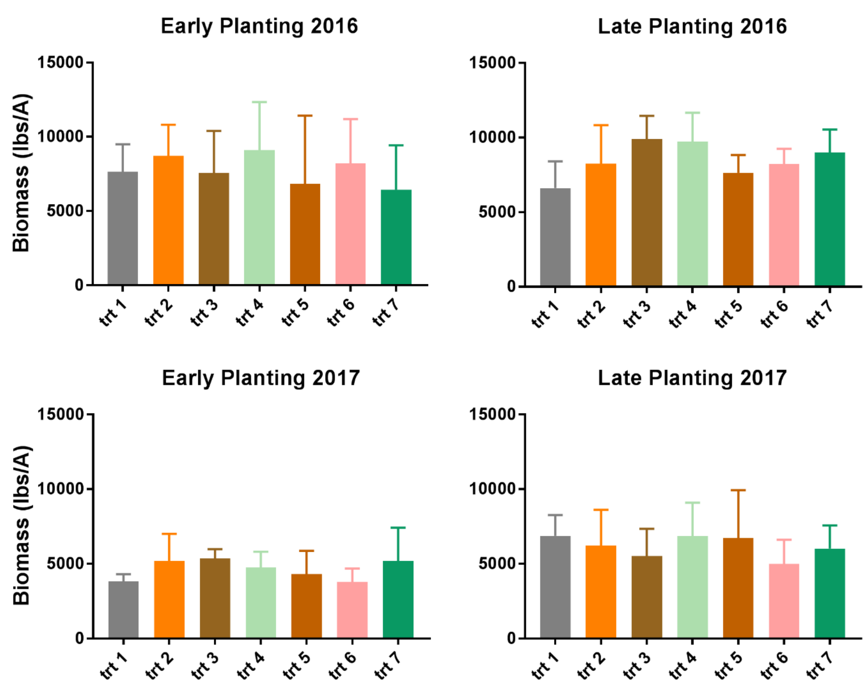

Figure 2. Dry biomass at growth stage R7 (maturity) for double-crop soybean, when planted early and late at Ashland Bottoms, KS, for 2016 and 2017.

Seed quality, fatty acids

Analysis of fatty acid methyl esters (FAMEs) was carried out as previously described (Li et al., 2006) with minor modifications. Pre-weighed crushed dry seeds were transmethylated with 2ml of 5% (v/v) sulfuric acid in methanol for 1 h at 90 oC. Before transmethylation, 200ug of tripentadecanoin was added as an internal standard and 50 µg of butylated hydroxytoluene was added to prevent oxidation. The FAMEs were then extracted with 1.5 mL of 0.9% (v/v) potassium chloride and 2 mL of hexane. The organic phase was analyzed with a Shimadzu GC-2010 plus gas chromatograph equipped with a DB-23 column (30.0 m x 0.25 mm; Agilent Technologies) coupled with flame ionization detector (GC-FID) as described previously (Aznar Moreno and Durrett, 2017). Content was calculated by the multiplication of the concentration of protein, oil and fatty acids by seed dry mass at harvest. Concentration is independent of the sample size; while content, extensive property, is size dependent (Farhoomand and Peterson, 1968).

Fatty acid yield was calculated by multiplying their concentrations by seed yield. Relative fatty acids were calculated using the proportions of each fatty acid to the total amount of fatty acids, generating a percentage of each fatty acid to the total.

Protein and oil

There were no differences in concentration for ash and fiber (Table 3). Yet, oil and protein concentration significantly differ among treatments, as well as protein content. Oil presented greater concentration for treatments 1 and 3, while there was lower concentration for treatment 5. On the other hand, there was greater protein concentration for treatments 4 and 5, while treatment 1 showed lower protein concentration. There were no significant differences for oil and protein concentrations for different planting dates.

Ash, fiber and protein were significantly lower for CP (Fig. 3). The kitchen sink treatment had greater content of protein, fiber and ash. Wide rows treatment also had greater content of protein. Despite there were no differences in treatments for ash concentration, ash content had similar responses to treatments as protein content, with greater content for treatments with higher inputs, except for treatment 3.

Biomass and seed yield showed significant positive correlation ($p < 0.001$, $r = 0.75$). As biomass increased, seed yield also increased. The same relation occurred for biomass and seed number ($p < 0.001$, $r = 0.68$), but in a very slight positive relationship with seed weight ($p < 0.05$, $r = 1.13$). Naturally, as biomass and seed yield had a positive relationship, but biomass showed a negative relation with harvest index ($p < 0.001$, $r = -0.55$). Seed yield and number were highly positively related ($p < 0.001$, $r = 0.93$), while seed weight and number showed a slightly negative relation ($p < 0.001$, $r = -0.24$).

Oil and protein portrayed an expected strong negative correlation among them ($p < 0.001$, $r = -0.80$). As seed weight increased, oil concentration decreased slightly ($p < 0.05$, $r = -0.17$) while protein increased slightly ($p < 0.05$, $r = 0.14$).

Table 3. Concentration and content of ash, fiber, oil and protein in soybean seeds at harvest. Treatments are as follows: 1) common practice (no inputs added), CP, 2) no seed treatment, NST; 3) non-stay green (without fungicide/insecticide application), NSG; 4) high plant density (450,000 seeds ha-1), HP; 5) wide rows, WR (75 cm); 6) N effect (without late-season fertilizer N), (NE); and 7) kitchen sink, KS, considering all the inputs evaluated in previous treatments (seed treatment, with fungicide and insecticide, high plant density, narrow rows (38 cm) and the addition of late-season N fertilization.

	Concentration													
	g kg^{-1}													
	1		2		3		4		5		6		7	
ash	52.93		53.12		53.03		53.20		53.23		53.21		53.16	
fiber	60.26		59.83		59.96		59.31		59.51		59.68		59.60	
oil	215.64	a	212.61	ab	214.26	a	211.97	ab	210.19	b	212.39	ab	212.68	ab
protein	390.78	b	395.47	ab	393.85	ab	399.49	a	401.66	a	396.62	ab	396.73	ab
	Content													
	g $seed^{-1}$													
	1		2		3		4		5		6		7	
ash	8.42	b	8.72	ab	8.52	b	8.65	ab	8.67	ab	8.64	ab	8.89	a
fiber	9.58	b	9.82	ab	9.63	ab	9.64	ab	9.69	ab	9.70	ab	9.97	a
oil	34.30		34.90		34.43		34.46		34.22		34.50		35.58	
protein	62.15	b	64.92	ab	63.28	ab	64.95	ab	65.39	a	64.43	ab	66.37	a

Fatty acids

Concentration of fatty acids did not differ among them (Table 4). Nonetheless, stearic acids content, showed statistical differences among treatments, being greater for treatment 2 and lower for treatment 3. Fatty acid yields showed increase in oleic, stearic, palmitic and total fatty acids for intensified management practices. The CP treatment presented less unsaturated fatty acid yield. Relative concentration showed significant differences for palmitic acid for treatments with greater inputs and lower values for CP treatment. There were no interactions or differences in early and late planting dates for fatty acid concentration, content, fatty acid yield or relative concentration.

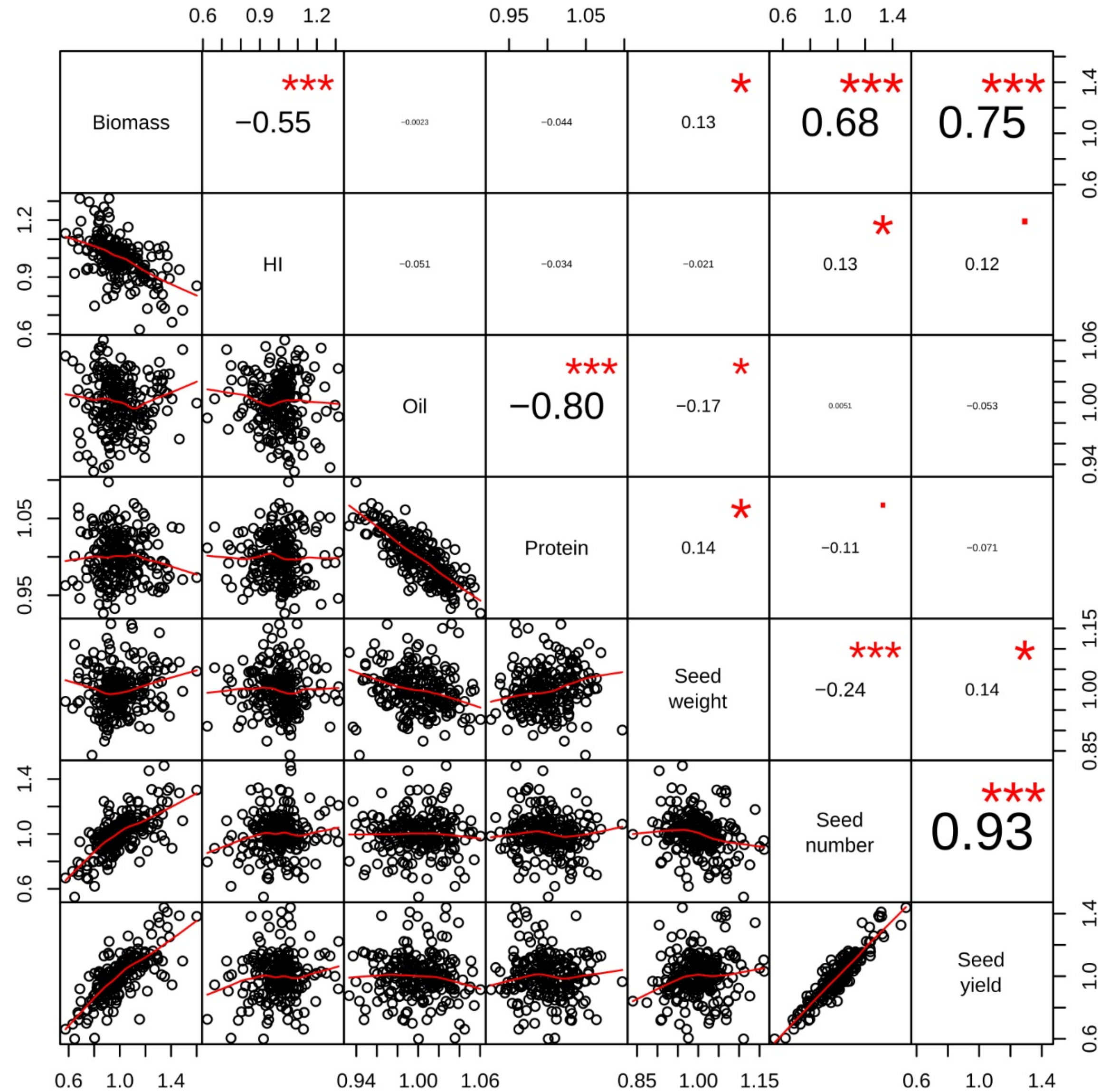

Figure 3. Correlation matrix comparing biomass, HI, oil, protein, seed weight, seed number and seed yield. On the bottom of the diagonal: the bivariate scatter plots with a fitted line are displayed (values for protein, oil, fiber and ash are expressed in %, seed is expressed in kg ha^{-1}). On the top of the diagonal: the value of the correlation (r) plus the significance level as stars. Each significance level is associated to a symbol: p-values (0.001, 0.05, 1) <=> symbols ("*", "*", " ").**

Table 4. Concentration, content, fatty acid yield and relative to total fatty acids.

	Concentration µg FAMEs mg^{-1}													
	1		2		3		4		5		6		7	
linolenic	17.54		17.44		17.23		17.45		17.16		17.40		17.45	
linoleic	126.69		125.24		122.50		125.24		122.39		123.97		124.23	
oleic	46.95		47.85		46.58		47.35		45.58		46.71		46.50	
stearic	8.40		8.58		8.17		8.36		8.19		8.30		8.31	
palmitic	25.33		25.35		25.14		25.57		25.18		25.42		25.26	
total	224.90		224.47		219.62		223.96		218.51		221.79		221.74	
	Content													
	mg $seed^{-1}$													
	1		2		3		4		5		6		7	
linolenic	2.79		2.86		2.77		2.84		2.79		2.83		2.92	
linoleic	20.15		20.56		19.68		20.36		19.93		20.14		20.78	
oleic	7.47		7.86		7.49		7.70		7.42		7.59		7.78	
stearic	1.34	ab	1.41	a	1.31	b	1.36	ab	1.33	ab	1.35	ab	1.39	ab
palmitic	4.03		4.16		4.04		4.16		4.10		4.13		4.23	
total	35.77		36.85		35.29		36.42		35.57		36.03		37.09	
	Fatty acid yield													
	kg ha^{-1}													
	1		2		3		4		5		6		7	
linolenic	30.9		35.6		33.1		34.5		32.6		32.5		33.9	
linoleic	92.0		103.1		101.0		104.3		99.6		98.9		101.7	
oleic	169.9	b	191.8	a	183.9	ab	190.6	ab	176.6	ab	180.5	ab	184.8	ab
stearic	64.1	b	71.6	a	70.0	ab	71.4	ab	67.9	ab	67.9	ab	70.9	ab
palmitic	461.9	b	512.2	a	493.9	ab	511.3	a	484.9	ab	482.3	ab	501.1	ab
total	818.9	b	914.3	a	881.9	ab	912.0	a	861.7	ab	862.2	ab	892.3	ab
	Relative to total fatty acids													
	mol% FAMEs													
	1		2		3		4		5		6		7	
linolenic	7.70		7.66		7.74		7.68		7.75		7.73		7.77	
linoleic	55.53		55.00		54.97		55.12		55.20		55.09		55.23	
oleic	20.59		21.03		20.93		20.86		20.59		20.78		20.67	
stearic	3.68		3.77		3.66		3.68		3.70		3.69		3.70	
palmitic	12.50	b	12.53	b	12.69	ab	12.66	ab	12.78	a	12.71	ab	12.63	ab

Conclusions

Despite early planting is beneficial when planting DC soybeans, in a year with not very well distributed rain events, it is critical to observe previous soil moisture and precipitation forecast, to guarantee good plant emergence and establishment of seedlings.

When planting DC soybean, it is strongly recommended to increase seed quantity. In adverse conditions, the greater seed number will help to maintain plant population at a recommended level.

Protein and oil have strong inverse concentration correlation. Protein concentration was lower when no inputs were applied, whilst oil presented greater concentration. There were no differences in concentration for fatty acids. However, for fatty acid yield, there were more monounsaturated fatty acids for treatments with more inputs, generating more high quality oil per area. Relative palmitic acid was lower when less inputs were applied. Fatty acids were all positively correlated among them. Seed filling duration can be affected by management practices, generating differences in seed composition at the end of the period. As the seed filling duration is longer, there is lower concentration of fatty acids but overall seed content of these components increase with the duration of seed filling.