Row Orientation and Configuration Effects on Canopy Light Spectra and Corn Growth

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Abstract. Recent popular-press articles have recommended planting rows in a north-south (N-S) orientation. However, effects of row orientation and configuration on light spectra within corn (*Zea mays* L.) canopies and the resultant growth response are not well defined. Field studies were conducted in 1985 and 1986 on Norfolk (fine-loamy, siliceous, thermic Typic Paleudult) loamy sand near Florence, SC, to measure those effects. Corn was planted in single rows spaced 76 cm (30 in.) apart and in twin rows spaced 19–57–19 cm (7–23–7 in.) apart. Rows were oriented in a N-S or east-west (E-W) direction. Canopy light spectra, vegetative response at growth stages (g.s.) V6 and R2, days to silking and tasseling, yield, and yield components were measured. Far red:red light ratios were calculated from spectral data. Leaf area, stalk length, and stalk diameter at g.s. V6 were not affected by row orientation or configuration. Rows planted in an E-W orientation yielded more than those planted N-S in 1985 but less in 1986. Row orientation has been shown to affect root and shoot development. This reversed yield response to orientation was presumably the result of early water stress in 1985 vs. late-season water stress in 1986. Previous studies showed an advantage for planting twin rows when compared to single rows spaced 96 cm (38 in.) or more apart, but there was no apparent advantage for twin rows when compared to single rows spaced 76 cm (30 in.) apart. These results suggest that for irrigated or nonwater stressed corn, maximum yield will occur when rows are spaced approximately 76 cm (30 in.) apart and planted in a N-S orientation.

Introduction

Row orientation and planting configuration are two management practices which can be varied [1, 12, 15, 16] without substantially increasing production costs. Grower interest in these types of plant manipulations is apparently increasing because recent reports in a popular farm magazine [19] have suggested that corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] yield can be increased by planting narrow strips using a N-S orientation. Row orientation and configuration (also defined as planting geometry) can influence natural bioregulation of plant morphogenesis and interception of photosynthetically-active, incident solar radiation (light) [2, 3]. This natural bioregulation of plant development occurs because row orientation and planting configuration can cause subtle changes in far-red:red (FR/R) light ratios that influence the plant phytochrome system [9, 13]. In broadleaf species, such as soybean, subtle changes in FR/R light ratios have been shown to influence partitioning of photosynthate among leaves, stems, roots, and developing seed [10].

Changes in row direction or plant density have been shown to change spectral light quality and influence soybean growth and development [13]. Soybean plants in north-south (N-S) rows received relatively more far-red light and developed longer internodes and fewer branches than plants in east-west (E-W) rows. Seed/straw ratios and number of seeds per pod also were affected. In controlled environment studies, partitioning of photosynthate between soybean shoots and roots was influenced by FR/R light ratios at the end of the photosynthetic period [10]. Nodule number was also increased on plants with larger root systems. These changes in plant growth characteristics are especially important for soybean grown on soils with low water and nutrient retention.

Evaluation of wheat (*Triticum aestivum* L.) grown in closely-, intermediately-, and widely-spaced field populations showed similar responses to FR/R light ratios. Closely-spaced seedlings received higher ratios than widely-spaced plants because of the larger amount of far-red light reflected from green leaves of the more numerous nearby plants. Those plants responded by producing fewer tillers, less roots, and longer leaves than widely-spaced seedlings under field conditions [11].

A recent survey evaluating row spacing effects

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for corn in seven southeastern states showed that grain yields increased by 5 to 10% by decreasing row spacing to 76 cm (30 in.) or less [7]. An alternate method that was demonstrated to improve plant distribution and yield was use of twin rows rather than single rows spaced 96 cm (38 in.) apart [5, 6]. A small amount of canopy spectra data was collected to support those conclusions, but early-season growth and development data were not collected, and row orientation effects were not determined.

Four equidistant plant spacings (0.3 × 0.3m, 0.6 × 0.6m, 0.9 × 0.9m, and 1.2 × 1.2m or 1 × 1 ft, 2 × 2 ft, 3 × 3 ft, and 4 × 4 ft) were evaluated in another corn experiment [14]. Canopy light spectra, including FR/R light ratios, as well as growth and development processes, were influenced significantly by plant spacing; but effects of row configuration and orientation were not separated from population effects. Therefore, field studies were conducted in 1985 and 1986 using single- and twin-row configurations planted at the same plant population in rows oriented either N-S or E-W. Objectives were 1) to quantify early- and mid-season light spectral patterns within the corn canopy; 2) to determine the effect of orientation and configuration on those spectral patterns; and 3) to measure corn growth and yield component responses to those management practices.

Methods and Materials

Field studies were conducted on Norfolk (fine-loamy, siliceous, thermic Typic Paleudult) loamy sand near Florence, SC, in 1985 and 1986. Preplant tillage consisted of disking to incorporate winter weeds and stubble from a previous soybean crop. Dolomitic limestone (1.1 Mg/ha or 0.5 t/A), N-P-K fertilizer (55-22-42 kg/ha or 50-20-37 lb/A), 3.4 kg/ha (3 lb/A) active ingredient (ai) of butylate (S-ethyl-diisobutyl-thiocarbamate) and 2.0 kg/ha ai (1.8 lb/A) of atrazine (2-chloro-4-ehtylamino-6-isopropyl amino-1,3,5-triazine) were broadcast and incorporated using a field cultivator prior to planting.

DeKalb-Pfizer Brand* T1100 hybrid corn was planted in single- and twin-row configurations on 30 April 1985, and 7 April 1986, in five 4-row (3 m or 10 ft) blocks 30 m (100 ft) long and oriented in either a N-S or E-W direction. Center-to-center spacing was 76 cm (30 in.) for both systems; thus, rows were either 76 or 19–57–19 cm (7–23–7 in.) apart. A 5 cm (2 in.) wide subsoil shank, angled forward nonparabolically with a 12 cm (4 in.) wide shoe, was centered between the twin rows or directly beneath the single rows. The shank penetrated to a depth of approximately 46 cm (18 in.) and thus disrupted a 20 cm (8 in.) thick, root-restrictive E horizon. Single-row configurations were planted with John Deere Flex-71 Unit Planters, while twin-row configurations were planted with a Kinzie experimental precision planter which alternately dropped seed in rows spaced 19 cm (7 in.) apart. Twin-row plots had the same plant density (5.2 plants/m^2 or 21,000 plants/A) as single-row plots, but plants were distributed in a triangular pattern.

The 1985 study was nonirrigated, but in 1986, both irrigated and nonirrigated treatments were evaluated. Supplemental irrigation water was applied using a solid-set, overhead irrigation system, when average soil-water tension at 20 cm (8 in.) exceeded 20 kPa (20 centibars) in the irrigated treatments. Five irrigations, totaling 12.5 cm (5 in.) of water, were applied in addition to 44 cm (17 in.) of rainfall that were received during the growing season. Two sidedress applications of 55 kg/ha (50 lb/A) N were applied four and seven weeks after seedling emergence.

Effects of row configuration and orientation on light spectra within the seedling canopy were determined by measuring light intensity at 5-nm (50-Å) intervals between 350 and 850 nm (3500 and 8500-Å). Incoming light was measured between 0800 and 0900 hrs EDT on the north, south, east, and west sides of individual, randomly-selected plants in both row configurations at growth stage V5 [17]. Data were collected using a 0.5 cm (0.2 in.) diameter light collector connected by a 150 cm (5 ft) fiber optic probe to a LiCor Model 1800 spectroradiometer. Duplicate scans were made at each sampling position.

Relative amounts of photosynthetically-active radiation (400 to 700 nm) intercepted by the canopy were calculated as a percentage of that in direct sunlight above the canopy. Spectral irradiances from 730 to 740 nm and from 640 to 650 nm were used to calculate FR/R ratios because these correspond to phytochrome action peaks in green plants [8].

Row configuration and orientation effects were evaluated at growth stage V6 in 1985 by collecting and fractionating two randomly selected plants from each 4-row block (10 plants per orientation and configuration treatment). Leaf number, leaf angle, width and length of the longest leaf, total leaf area, stalk length and diameter, and number of suckers were determined. At growth stage R2, the same parameters plus the number of developing ear shoots were measured again. The number of days between seedling emergence and appearance of tassels and silks was recorded to determine if male and/or female flower development were affected by either row configuration or orientation. At physiological maturity (fully developed black layer with no visible milk line), the number of kernel rows per ear, kernels per row, weight of 100

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seed, and weight of the cob, were measured for 100 randomly selected ears (20 per 4-row block). Grain yield in kg/ha (bu/A) was extrapolated for comparative purposes, but the amount of grain harvested from the research site closely paralleled the yield estimates.

In 1986, the number of days between plant emergence and tasseling or silking was recorded, but other vegetative samplings were not made because of the small differences recorded in 1985. At physiological maturity in 1986, the same parameters were measured as in 1985, but only 10 randomly selected ears (two per 4-row block) were evaluated. All data were analyzed statistically using a general linear model [18] as shown in Equation (1).

$$\text{Model Y} = \text{orientation configuration plant orientation} \times \text{configuration} \quad (1)$$

Least significant difference (LSD) values were calculated only if F tests were significant at $P < 0.10$.

Results and Discussion

Canopy light measurements (Table 1) were made when corn plants were at growth stage V5, because previous studies with broadleaf crops, such as soybean, southern pea (*Vigna unguiculata* L.) and tobacco (*Nicotiana tabacum* L.), showed that subtle changes in FR/R light ratio received by young plants could influence plant growth and development as well as photosynthate partitioning [9, 12]. Early-morning FR/R light measurements were made, because they would be similar in magnitude to that received near the end of each day. This type of measurement is important to understand the effects of row orientation and configuration, because proximity of neighboring plants influences the amount of reflected FR [13] and the magnitude of FR/R light ratios.

The east side of plants in N-S rows was on the sunny side during the morning and, therefore, had a FR/R ratio that was very similar (0.92) to the 0.88 ratio in direct sunlight at that time. Evening measurements would result in similar ratios, although low FR/R ratios and higher PPFD values would be found on the west side of those plants rather than on the east side. Higher FR/R ratios indicate that more FR light is reflected from or transmitted through plants in adjacent rows. Photosynthetic photon flux density (PPFD) measurements confirmed this; because when the sensor was pointed in a N, S, E, or W direction, most incoming radiation was indirect. The exception during morning measurements was on the east side of plants in N-S rows. Plants in E-W rows showed less variation in FR/R ratios. This row orientation effect on FR/R

Table 1. Row orientation effects on canopy light measurements on the north (N), south (S), east (E), and west (W) sides of V5 corn plants at 0800 hours eastern daylight time on 5 June 1985

Row orientation	Side of plant N	S	E	W
	Far-Red: Red light ratio			
N–S	1.54	1.19	0.92	1.40
E–W	1.21	1.20	1.43	1.48
	Incident of PPFD[a] (%)			
N–S	14.6	19.8	65.3	10.3
E–W	16.1	16.5	15.8	13.2

[a] PPFD = photosynthetic photon flux density

ratios was similar to that for soybean [10], except that differences were smaller for corn. Heliotropic (light seeking or tracking) leaf movement was presumably responsible for the greater difference in FR/R ratios due to row orientation for broadleaf species, such as soybean and southern pea [13].

Plant characteristics, including stalk length and diameter, leaf number, length and width of the largest leaf, total leaf area, and fresh weight for leaves, sheaths, and stalks, were measured at growth stage V6 to evaluate orientation and configuration effects of plant growth. Plants had 12 visible leaves at this stage with the largest one averaging 82 cm (32 in.) in length and 10 cm (3.9 in.) in width. Stalk length averaged 50 cm (20 in.), diameter 2.8 cm (1.1 in.) and leaf area 5100 cm^2 (790 $in.^2$) for randomly selected plants being grown at a population of 5.2 plants/m^2 (21,000 plants/A). There were no significant orientation or configuration effects on plant growth or development at this growth stage. Similar data collected for plants in an equidistant spacing study [14] showed significant differences for each of these parameters associated with number and nearness of competing plants.

Flower initiation is another developmental process that can be influenced by subtle changes in light spectra [8]. There were no significant effects for row configuration in either year. In 1985, there was a statistically significant difference in the number of days between seedling emergence and tasseling for rows planted in N-S vs. E-W orientation, but the difference was not agronomically meaningful because it was only 0.2/day. Sampling error could have contributed to this effect, but highly significant differences for both tassel and silk emergence in the equidistant study [14] suggest that sampling was not the only factor involved. In 1986, row orientation did not significantly influence the

Table 2. Row orientation effects on yield and yield components of corn in 1985 and 1986

Row orientation	Dry grain yield (g/plt)	Dry grain yield (Mg/ha)	Kernel rows per ear (no.)	Kernels per row (no.)	100-Seed weight (g)	Cob weight (g)
			1985 nonirrigated			
N–S	116[a]	6.0[b]	16.5	33.6	27.6	17.9
E–W	131	6.8	17.0	32.4	28.0	18.9
LSD (0.10)	5	0.2	0.2	1.0	ns	0.6
			1986 nonirrigated			
N–S	102	5.3	18.6	36.0	18.4	22.3
E–W	102	5.3	17.4	33.2	19.3	18.2
LSD (0.10)	ns	ns	0.6	1.9	0.8	1.9
			1986 irrigated			
N–S	183	9.4	18.0	38.9	27.2	28.0
E–W	164	8.5	17.0	37.2	29.1	24.7
LSD (0.10)	8	0.4	0.6	ns	1.1	1.3

[a] To convert gram (g) to ounces (oz), divide by 28.35.
[b] To convert to bu/A, divide by 0.0628.

number of days to tasseling; and for this population, there were no significant differences in the number of days between seedling emergence and silk emergence in either year.

Leaf area measurements at growth stage R2 averaged 6714 cm^2/plant (1041 $in.^2$/plant) in 1985 but showed no significant differences for either row orientation or configuration. This amount of leaf area provided a leaf area index (LAI) of 3.5, which previous studies [7] showed was sufficient to intercept 98% of the photosynthetically-active radiation (PAR) before it reached the soil surface. Dry leaf weight was significantly lower for plants grown in a N-S orientation rather than in an E-W orientation (44.1 vs. 47.2 g/plant or 1.6 vs. 1.7 oz/plant, respectively) and for plants grown in single rows rather than twin rows (44.1 vs. 47.2 g/plant or 1.6 vs. 1.7 oz/plant, respectively). Stalk weight for plants in the N-S orientation or single-row configuration was lower than for the E-W orientation or twin-row configuration (71 vs. 77 g/plant or 2.50 vs. 2.7 oz/plant).

Row orientation effects on corn yield components are summarized in Table 2. Consistent with vegetative measurements at growth stage R2, plants in E-W rows yielded more than those in N-S rows in 1985. This yield increase occurred because of a significantly higher number of rows of kernels on ears from plants grown in E-W orientation, since the number of kernels per row was significantly lower and kernel weight was not different. A significantly higher cob weight suggested that ears from E-W plants were also larger. The 1985 study was nonirrigated, and since only 76 mm of rain fell between 1 April and 1 June, water stress occurred early in the season. Therefore, corn yield component response to E-W orientation was similar to that for nonirrigated soybean [4].

Late-season water stress for nonirrigated corn was very severe in 1986, when only 77 mm (3.0 in.) of rain fell between 1 June and 20 July. Pollination and early reproductive growth occurred during this period. This water stress caused lower 100-seed weights for N-S plants than for E-W plants and presumably eliminated a yield response to orientation, even though row number, kernel number, and cob weight were significantly greater (Table 2). With supplemental irrigation, plants in N-S rows yielded significantly more grain and also had greater row number, kernel number, and cob weight than plants in E-W rows. This result was consistent with that for soybean [4] which showed that, without water stress, higher yields were obtained in N-S rows than in E-W rows.

The yield component response to row orientation in 1986, based on previous research with soybean [12], may have been caused by greater partitioning of photosynthate to shoots than to roots in N-S rows, although root samples were not collected in this study. This suggests that during vegetative growth stages in 1986, conditions were more favorable for establishing potential yield than in 1985. This hypothesis was consistent with rainfall data for March, April, and May, which totaled 103 mm (4 in.) in 1985 and 197 mm (7.8 in.) in 1986. Lower kernel weight in 1986, however, indicates that, even

Table 3. Row configuration effects on yield and yield components of corn in 1985 and 1986

Row configuration	Dry grain yield (g/plt)	Dry grain yield (mg/ha)	Kernel rows per ear (no.)	Kernels per row (no.)	100-Seed weight (g)	Cob weight (g)
			1985 nonirrigated			
Single	130[a]	6.7[b]	16.5	34.5	28.4	19.6
Twin	116	6.0	17.0	31.5	27.3	17.1
LSD (0.10)	5	0.2	0.2	1.0	0.5	0.6
			1986 nonirrigated			
Single	108	5.6	17.9	35.6	19.0	21.0
Twin	96	5.0	18.1	33.6	18.7	19.6
LSD (0.10)	11	0.6	ns	1.9	ns	ns
			1986 irrigated			
Single	178	9.2	17.6	38.2	27.8	26.0
Twin	168	8.7	17.4	38.0	28.5	26.6
LSD (0.10)	8	0.4	ns	ns	ns	ns

[a] To convert gram (g) to ounces (oz) divide by 28.35.
[b] To convert to bu/A, divide by 0.0628.

with supplemental irrigation, plants in N-S rows were less able to tolerate drought during reproductive stages.

Effects of row configuration on grain yield and yield components are summarized in Table 3. The twin-row configuration yielded less than the single-row configuration in both years. This response was the same as found previously for the DeKalb-Pfizer Brand T1100 hybrid [7] but opposite to that found with an erect leaf Pioneer Brand 3382 hybrid [5]. A lower number of kernels per row for the twin-row treatments is the apparent physiologic reason for lower yield. The cause for this is not known, but changing average row spacing from 96 to 76 cm (38 to 30 in.) was apparently sufficient to eliminate the twin-row advantage that was demonstrated previously [5, 6].

In summary, this 2-year field study showed that row orientation had less effect of FR/R light ratios in corn canopies than was previously observed in soybean canopies. Use of a N-S row orientation under nonstressed conditions may offer a yield advantage because of more rows of kernels and kernels per row, but plants must not be stressed for water or nutrients or the advantage can easily be lost during grain fill because of lower kernel weight. Finally, use of a twin-row planting configuration did not increase grain yield when compared to single rows spaced 76 cm (30 in.) apart.

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