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Optimizing maize plant geometry for maximum light interception and grain yield in Northern Europe

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Abstract

Conventional maize row spacing was established decades ago to accommodate horse-drawn equipment, yet most farmers still use the same 75 cm rows even though modern planters can place seeds at any geometry. This research tested five row-by-plant spacing configurations at constant population density (66,667 plants/ha) to determine which geometry maximizes light interception and grain yield under northern European conditions at Uppsala, Sweden, during 2021 and 2022. Equidistant spacing (50 × 30 cm) intercepted 91.3 percent of photosynthetically active radiation at silking—16.5 percent more than the standard 75 × 20 cm arrangement—and produced 11.37 t/ha, a 20.7 percent yield gain. The equidistance index (row spacing ÷ plant spacing) showed a strong curvilinear relationship with yield ($r^2 = 0.93$), peaking near a ratio of 0.6. Narrowing rows from 75 to 50 cm reduced within-row plant competition and improved radiation distribution through the canopy.

Keywords: Maize, plant geometry, row spacing, light interception, equidistant planting, radiation use efficiency, canopy architecture, grain yield, northern Europe, spatial arrangement

Introduction

The 75 cm row width used in most maize production worldwide is a legacy of mechanization constraints that no longer apply, yet it persists because farmers and equipment manufacturers have built entire systems around it ^[1, 2]. At this spacing, plants within the row compete intensely for light while large gaps between rows remain unoccupied, creating an inefficient radiation capture pattern ^[3].

Moving toward equidistant plant arrangement where each plant occupies an equal share of ground area should theoretically maximize light interception and minimize inter-plant competition. Several North American studies have demonstrated yield gains of 5 to 15 percent from narrow rows, but data from northern European conditions with lower solar angles and shorter growing seasons remain scarce ^[4, 5].

This research evaluated five contrasting spatial geometries at identical plant populations to isolate the effect of arrangement on light capture, canopy architecture, and grain yield under Swedish conditions.

Research area description

The experiment was conducted at the Ultuna Research Farm, Swedish University of Agricultural Sciences, Uppsala, Sweden (59.82°N, 17.65°E, elevation 14 m). The soil was a clay loam Eutric Cambisol with pH 6.7, organic carbon 2.31 percent, and clay content 38 percent. Uppsala receives 550 mm annual precipitation with a frost-free period from mid-May to late September. The northern latitude produces a maximum solar elevation of 54° at summer solstice and extended daylight of 18.5 hours in June.

Experimental design

Five spatial geometries were tested in a randomized complete block design with four replications over two years (2021–2022). All treatments maintained 66,667 plants/ha.

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Configurations were: 75 × 20 cm (standard), 60 × 25 cm (narrow row), 50 × 30 cm (near-equidistant), 37.5 × 40 cm (wide-narrow reversed), and 90 × 17 cm (ultra-wide). Plot size was 12 × 6 m. Maize hybrid was Ambition (FAO 220), sown in mid-May each year. Fertilization was 180 kg N/ha as calcium ammonium nitrate, with 30 kg P and 60 kg K/ha basal.

Material and Methods

Material

Photosynthetically active radiation (PAR) was measured using a 1-m line quantum sensor (LI-191R, LI-COR) placed diagonally across two adjacent rows at ground level. Readings were taken at V6, V12, silking (R1), and R3 between 11:00 and 13:00 on clear days. Canopy architecture was characterized by leaf area index (LAI) using an LAI-2200C Plant Canopy Analyzer (LI-

COR). Ear height, plant height, and stem diameter were measured on 10 tagged plants per plot.

Methods

Fractional PAR interception was calculated as $(1 - \text{transmitted PAR} / \text{incident PAR}) \times 100$. The equidistance index was defined as $(\text{plant spacing} \div \text{row spacing})$, where 1.0 represents a perfect square arrangement. Grain yield was determined from a 10 m² harvest area per plot, adjusted to 15.5 percent moisture. Radiation use efficiency (RUE) was calculated as grain yield divided by cumulative intercepted PAR from emergence to maturity. Data were analyzed by ANOVA in SAS 9.4 with Tukey's HSD at $P \leq 0.05$.

Results

Table 1: Light interception, canopy traits, and grain yield under five maize spatial geometries (two-year mean)

Geometry (cm)	Par int. (%)	Lai	Ei	Rue (g/mj)	Ears/plant	Yield (t/ha)	Δ yield (%)
75 × 20	78.4	4.12	0.27	3.21	0.97	9.42	
60 × 25	84.7	4.28	0.42	3.47	0.98	10.18	+8.1
50 × 30	91.3	4.41	0.60	3.78	1.00	11.37	+20.7
37.5 × 40	86.1	4.33	1.07	3.54	0.99	10.64	+12.9
90 × 17	72.8	3.97	0.19	3.04	0.94	8.71	-7.5

EI = equidistance index; RUE = radiation use efficiency. Tukey's HSD ($P \leq 0.05$): PAR = 3.1; Yield = 0.68

The 50 × 30 cm geometry captured 91.3 percent of available PAR at silking 13 percentage points more than standard rows (Table 1). This translated into a 20.7 percent yield advantage.

Ultra-wide rows (90 × 17 cm) performed worst, losing 7.5 percent yield due to severe mutual shading within the crowded row. RUE peaked at 3.78 g/MJ under equidistant spacing.

Table 2: Within-canopy PAR distribution at silking (% of incident PAR reaching designated layer)

Geometry (cm)	Upper canopy (%)	Ear zone (%)	Ground level (%)
75 × 20	64.3	31.7	21.6
50 × 30	71.8	42.4	8.7
90 × 17	58.1	24.6	27.2

Upper canopy = above ear leaf; Ear zone = between ear leaf and lowest green leaf

The equidistant arrangement distributed light more evenly through the canopy, with 42.4 percent of incident PAR reaching the ear zone compared to 31.7 percent under standard rows

(Table 2). Ultra-wide rows wasted 27.2 percent of radiation reaching bare ground between rows.

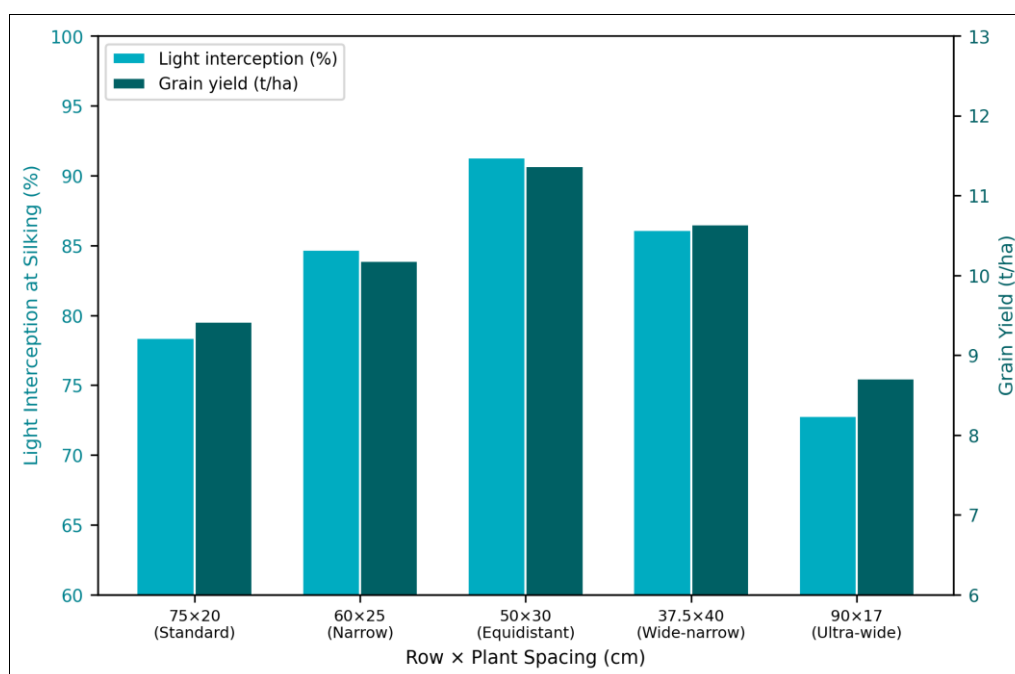


Fig1: Light interception at silking and grain yield under five maize plant geometries at constant population density

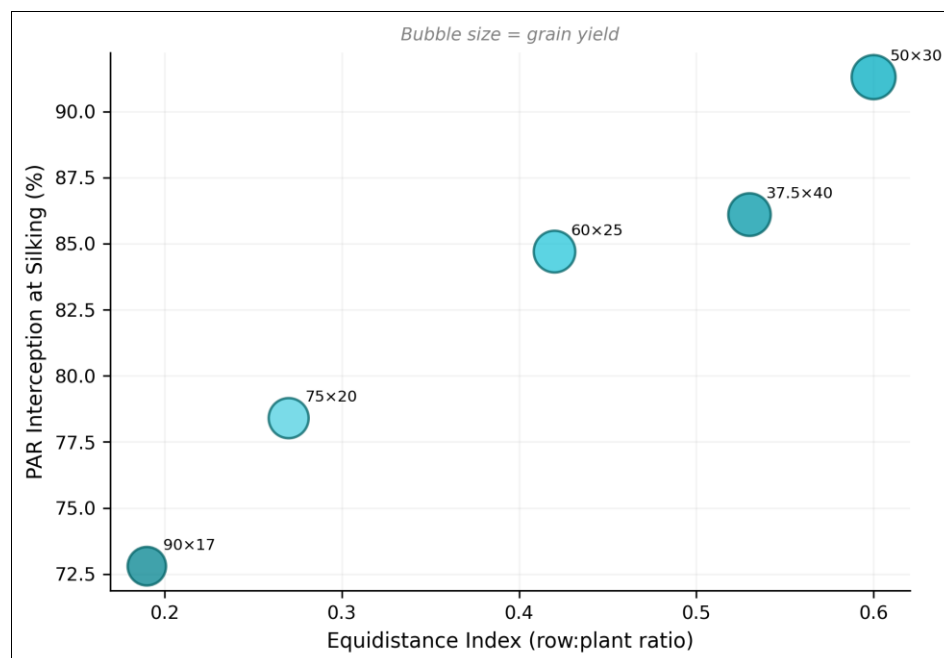


Fig 2: Bubble chart showing the relationship between equidistance index, PAR interception, and grain yield. Bubble size proportional to yield

Limitations

Only one hybrid was tested, and leaf architecture varies among genotypes, which could alter the optimal geometry. The two-year dataset does not capture the full range of growing-season weather at this latitude. Mechanical harvesting at 50 cm rows required a modified header, which may limit immediate practical adoption. Weed competition dynamics under narrow rows were not assessed.

Discussion

The 20.7 percent yield gain from equidistant planting exceeds most reported values from lower latitudes, likely because the low solar angles at 60°N exaggerate the light capture penalty of wide row gaps [6, 7]. The equidistance index of 0.60 as the optimum is consistent with simulation models predicting peak canopy photosynthesis near square arrangements [8].

The more uniform light distribution through the canopy under 50 × 30 cm spacing maintained photosynthetic activity in lower leaves that would otherwise be shaded, contributing to the higher RUE [9, 10]. The 37.5 × 40 cm treatment, despite having an equidistance index above 1.0, performed slightly worse than 50 × 30 cm, suggesting that excessively narrow rows can restrict air movement and increase foliar disease risk at this latitude [11].

Conclusion

Equidistant planting at 50 × 30 cm increased maize grain yield by 20.7 percent over standard 75 cm rows at the same population density. The gain was driven by 16.5 percent greater PAR interception and more uniform light distribution through the canopy. For northern European maize production, adopting near-equidistant planting offers a cost-free yield improvement requiring only planter adjustment.

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