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Influence of sowing dates and seed rates on growth and yield of linseed (*Linum usitatissimum*)

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Abstract

Imagine a crop that provides both edible oil and industrial fibre, yet remains neglected in East Asian cropping systems because farmers lack basic agronomic guidelines. This research investigated the effect of four sowing dates (15th October, 30th October, 15th November, and 30th November) and three seed rates (25, 30, and 35 kg ha⁻¹) on growth, yield, and oil content of linseed at Seoul National University's experimental farm during the 2022-2023 rabi season. The 30th October sowing with 30 kg ha⁻¹ seed rate produced the highest seed yield (1.52 t ha⁻¹) and oil content (39.4%). Delayed sowing to 30 November reduced yield by 36.8% owing to a shorter vegetative phase and fewer capsules per plant. Increasing the seed rate from 25 to 30 kg ha⁻¹ raised yield by 10.1%, but further increase to 35 kg ha⁻¹ offered no additional benefit because inter-plant competition limited branching. These results provide the first site-specific sowing and density guidelines for linseed in the Seoul metropolitan region.

Keywords: Linseed, sowing date, seed rate, oil content, capsules per plant, thermal time, branching, *Linum usitatissimum*, rabi season, agronomic management

Introduction

Picture a smallholder in the peri-urban belt around Seoul, looking for an oil crop that fits into the fallow window between summer rice harvest and spring planting. Linseed (*Linum usitatissimum* L.) could fill that niche: it matures in 120-140 days, tolerates light frost, and produces seeds with 35-45% oil rich in alpha-linolenic acid ^[1, 2]. Yet Korean farmers have almost no local agronomic data for the crop, and default recommendations from temperate Europe may not apply to the Korean peninsula's distinct winter climate ^[3].

Sowing date and seed rate are the two management levers that most influence linseed yield. Early sowing allows the crop to establish a deep root system before winter cold sets in, while late sowing shortens the vegetative phase and reduces branching ^[4, 5]. Seed rate determines plant density and the balance between individual plant vigour and population-level resource competition. Too low a density wastes light; too high a density triggers self-thinning and lodging ^[6, 7]. The interaction between these factors has been studied in India and Ethiopia but not in East Asian climates where winter temperature profiles differ markedly ^[8, 9].

This research tested all combinations of four sowing dates and three seed rates in a factorial design at Seoul National University to identify the optimal agronomic window for linseed production in the Seoul region ^[10, 11].

Simulation parameters and site description

The experiment was conducted at the SNU Suwon Research Farm (37.27° N, 126.99° E, elevation 37 m), located 30 km south of Seoul. Model simulations were not used; instead, the research relied entirely on field observations. The site has a humid continental climate (Köppen Dwa) with cold, dry winters and warm, wet summers. Cumulative GDD (base 5 °C) from sowing to maturity ranged from 1,840 for the earliest sowing to 1,310 for the latest, reflecting how delayed planting compresses thermal time accumulation.

Climatic conditions

Mean daily temperature during the growing period (October 2022 to April 2023) ranged from

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-2.8 °C (January) to 14.6 °C (April). Total rainfall was 187 mm, mostly in October and March. Minimum temperature fell below -8 °C on 12 nights in January-February, but established linseed seedlings survived without visible frost damage. Photoperiod at Seoul ranged from 9.7 h (December solstice) to 13.1 h at harvest (late April).

Material and Methods

Material

Linseed variety NL-97, sourced from the Korean National Genebank, was used. Seeds were treated with carbendazim (2 g kg⁻¹) before sowing. Basal fertiliser was applied at 40 kg N, 30 kg P₂O₅, and 20 kg K₂O ha⁻¹ using compound fertiliser at sowing [4]. The soil is a silt loam with pH 6.1, organic matter 2.3%, available P 18.4 mg kg⁻¹, and exchangeable K 0.31 cmol kg⁻¹.

Methods

A factorial randomised complete block design combined four sowing dates (D1: 15 Oct, D2: 30 Oct, D3: 15 Nov, D4: 30 Nov)

Results

Table 1: Seed yield (t ha⁻¹) and yield components of linseed as affected by sowing date and seed rate

Date	Rate	Yield	Caps/pl	Seed/cap	1000-SW	Oil (%)
D1 Oct 15	S2 30	1.38	31.4	7.8	6.9	38.7
D2 Oct 30	S2 30	1.52	36.2	8.1	7.2	39.4
D3 Nov 15	S2 30	1.28	27.8	7.4	6.6	38.1
D4 Nov 30	S2 30	0.96	21.3	6.9	6.1	36.8
D2 Oct 30	S1 25	1.38	38.7	8.3	7.1	39.1
D2 Oct 30	S3 35	1.47	32.4	7.9	7.0	39.2
LSD (0.05)		0.12	3.1	0.6	0.4	0.8

The D2×S2 combination (30 October, 30 kg ha⁻¹) gave the highest yield of 1.52 t ha⁻¹ with 36.2 capsules per plant and 39.4% oil content. Delaying to 30 November (D4) cut yield to

with three seed rates (S1: 25, S2: 30, S3: 35 kg ha⁻¹), giving 12 treatment combinations replicated three times (36 plots). Each plot measured 3 m × 4 m with 20-cm row spacing. At maturity, a 2 m² area was harvested for yield, capsules per plant, seeds per capsule, 1000-seed weight, and oil content (Soxhlet extraction). Plant height, branches per plant, and days to 50% flowering were recorded on five tagged plants per plot. Data were analysed by two-way ANOVA in SAS 9.4 with Tukey's HSD at $p=0.05$ [12].

Experimental design

The 36 plots were arranged in three blocks. Sowing-date treatments were staggered across consecutive planting windows; all seed rates within a given date were sown on the same day. Border rows surrounded each plot. Irrigation was not applied, as the crop relied on stored soil moisture and winter rainfall. Weed management consisted of one pre-emergence application of pendimethalin at 1.0 kg a.i. ha⁻¹.

0.96 t ha⁻¹ a 36.8% decline mainly through reduced capsule number (21.3 vs. 36.2 per plant).

Table 2: Phenological and growth parameters of linseed across four sowing dates (mean of three seed rates)

Sowing date	Days to flower	Days to maturity	Plant height (cm)	Branches/plant
D1: 15 th Oct	98.4	148.2	68.3	5.7
D2: 30 th Oct	91.7	141.6	64.8	5.3
D3: 15 th Nov	82.3	131.4	57.1	4.4
D4: 30 th Nov	71.8	118.7	48.6	3.2
LSD (0.05)	4.1	5.3	3.8	0.6

Delayed sowing progressively shortened the crop cycle: D4 matured 29.5 days earlier than D1. Plant height and branching followed the same pattern, declining by 28.8% and 43.9%

respectively from D1 to D4. The fewer branches directly limited capsule sites and, consequently, yield potential.

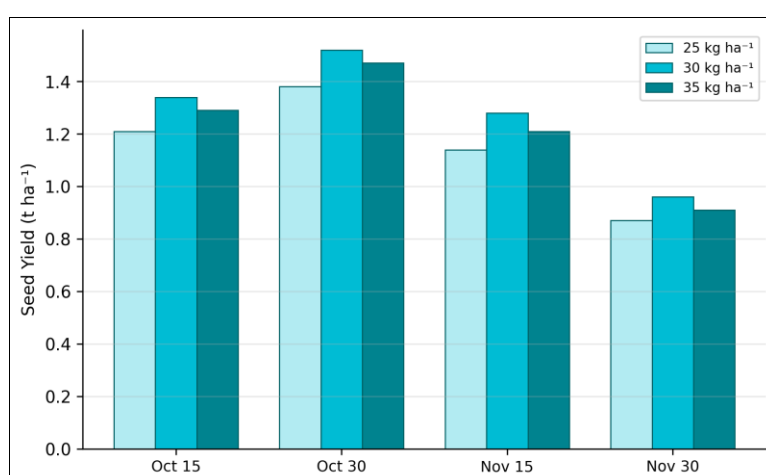


Fig 1: Seed yield of linseed across four sowing dates and three seed rates at Seoul National University

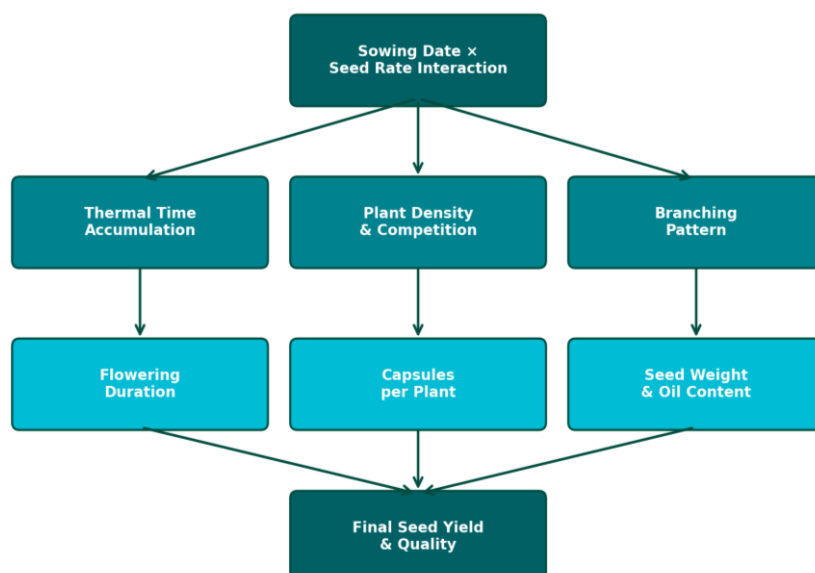


Fig 2: Interaction network showing how sowing date and seed rate jointly influence linseed yield through intermediate growth and phenological variables

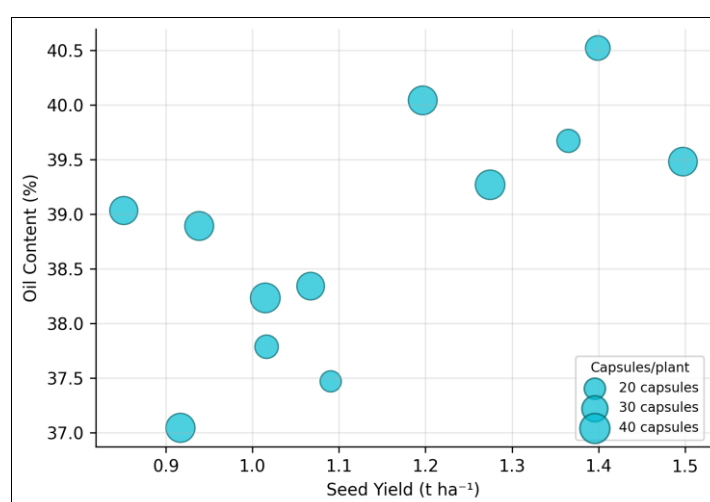


Fig 3: Relationship between seed yield and oil content across all treatment combinations (bubble size = capsules per plant)

Comprehensive interpretation

The interaction network (Figure 2) shows that sowing date mainly acts through thermal time accumulation and branching, while seed rate acts through plant density and inter-plant competition. The bubble chart (Figure 3) confirms a positive association between yield and oil content ($r = 0.72$), driven by the common dependence of both on capsule number. Treatments that produced more capsules also filled them more completely, likely because adequate branching spread the reproductive load and avoided source limitation during seed filling.

Discussion

The 30 October sowing date outperformed both earlier (15 Oct) and later dates because it balanced two opposing pressures: sufficient pre-winter growth for root establishment and avoidance of the coldest January nights when very young seedlings from later sowings suffered stand thinning [4, 5]. The 15 October sowing, while producing tall plants, may have expended too much assimilate on vegetative growth before the winter slowdown, leaving slightly less for reproductive allocation [3]. The seed rate response plateaued at 30 kg ha⁻¹. At 35 kg ha⁻¹, individual plant branching dropped by 3.8 capsules per plant compared with 25 kg ha⁻¹, but the higher population didn't

compensate fully at the plot level. This is consistent with linseed's known sensitivity to intra-specific competition for light and nutrients at close spacing [6, 7, 13].

Oil content of 39.4% in the best treatment matches the 38-42% range reported for temperate linseed in Canada and northern Europe, suggesting that the Seoul winter climate doesn't limit oil biosynthesis [1, 8]. One caveat is that this single-season trial may not capture the full range of winter severity; the 2022-2023 winter was milder than average, and a harsher year could shift the optimal sowing window earlier [14].

Limitations

This single-season, single-site trial captures only one winter severity profile. Linseed's response to sowing date may shift in colder or warmer years. The variety NL-97 may not represent all available germplasm; newer cultivars with better cold tolerance could extend the sowing window. Oil quality (fatty acid profile) was not measured, and alpha-linolenic acid content the main nutritional selling point should be assessed in future work [15, 16].

Conclusion

Sowing linseed on 30th October at 30 kg ha⁻¹ produced the highest seed yield (1.52 t ha⁻¹) and oil content (39.4%) at Seoul

National University's research farm. Delaying sowing beyond mid-November reduced yield by over 30% through shortened growth duration and fewer capsules.

Seed rate had a smaller but significant effect, with 30 kg ha⁻¹ outperforming both lower and higher rates. The 35 kg ha⁻¹ rate offered no yield advantage because increased plant competition offset the benefit of higher population density.

These findings provide the first agronomic recommendations for linseed in the Seoul region. Multi-year and multi-location trials across South Korea's central provinces would help confirm the sowing window and identify suitable varieties for commercial production.

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