Spatial planting patterns in winter wheat

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Summary

A 2023 winter wheat trial demonstrated a yield benefit of 1.0 t/ha from precision planting on a grid pattern with each seed equidistant from other seeds, relative to conventional drilling on narrow (12.5 cm) rows. The trial also showed disadvantages from wide (25 cm) row spacings – reduced light interception, increased height and increased lodging – which did not reduce yield on this occasional relative to narrower rows, but could be expected to in a light-limited situation.

When combined with earlier data suggesting yield benefits from more evenly spaced plants in winter wheat – whether achieved by narrower rows, cross-drilling or precision planting – this trial shows that further research into row spacing and precision planting in UK cereals could lead to significant yield benefits.

This trial was initiated by Oxfordshire farmer David Passmore. After trial establishment, funding was secured from Defra's Farming Innovation Programme (Research Starter 2 Competition, delivered in partnership with Innovate UK) for David's own work on the trial and for project support from ADAS and NIAB.

Background: wide row spacing – a problem for yield?

A possible contributor to the yield plateau in UK wheat – the lack of improvement in average farm yields over the last 25 years – is the trend for the industry to increase row spacings. In wide rows, the seeds are necessarily closer together within the row than when planted in narrower rows. This is expected to cause crowding and competition between plants in the same row and perhaps inefficient resource capture between rows, particularly of light, in the early part of the season. This effect is somewhat mitigated by drills which sow a band rather than a row of plants.

Logically, if plant crowding can be reduced and resource capture improved by moving from wide to narrow rows, there could be further improvement from moving to precision planting or seed singulation. This is because in conventional drilling, seed spacing within rows is random; as seeds are trickled down the coulter of the drill, there may be clusters of seeds in some places and larger gaps in others.

The hypothesis that more evenly spaced seeds can increase yield by reducing plant crowding and improving light capture is supported by numerous earlier projects, including:

- Analysis of the data from the ADAS Cereal YEN[1] has shown an association between narrower row spacing and higher yield.
- A previous experiment by innovative farmer David Passmore (Oxfordshire), supported by Rothamsted FarmInn, found a 0.7 t/ha yield benefit of cross-drilling winter wheat (drilling half the seed rate in 12.5cm rows then drilling half seed rate again at 90° to the first pass), compared to the same total seed rate in 12.5cm rows.

[1] https://yen.adas.co.uk/

- Similar cross-drilling trials in oilseed rape, in association with YEN, showed yield benefits of cross-drilling over wide row spacings.
- Michigan State University have shown a 10% yield increase from precision planting compared with conventionally drilled wheat[2]. They have also found yield benefits of narrow rows compared with wide rows.
- A review of older research showed yield benefits of narrow rows over wide row spacing across a range of seeding densities and canopy types[3], and that light interception and yield were optimised with plants in arranged in a hexagonal (honeycomb) spatial pattern[4].

Methods: a proof-of-concept trial in winter wheat

To test the hypothesis that more evenly spaced seeds will increase wheat yield, long-term YEN member David Passmore set out a small plot experiment (2.5m x 5m plots) on his mixed farm in Oxfordshire. The experiment included four treatments, each replicated four times in randomised blocks:

- Wide (25cm) row spacing (360 seeds/m^2)
- Conventional (12.5cm) row spacing (360 seeds/m^2)
- Cross-drilling (perpendicular 12.5cm rows) (360 seeds/m^2)
- Precision planting (hand planting on a triangular grid pattern) (200 seeds/m^2)

A lower seed rate was used in the precision planting treatment than the other treatments because the well-spaced plants were expected to be able to compensate for a lower seed rate by tillering, and to reduce the time required for hand planting; even at this lower seed rate, there were 10,000 seeds to be hand-planted.

The variety was KWS Zyatt, grown for seed, and all planting treatments received the same farm standard programme of fertilisers, PGRs and crop protection treatments.

Figure 1. 25cm wide rows (left) and precision-planted crop with seeds equally spaced in a triangular grid pattern (right) in January 2023.

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[2] https://www.canr.msu.edu/news/conventional-drill-versus-precision-planting-in-wheat

[3] Stoskopf NC (1967) Yield performance of upright-leaved selections of winter wheat in narrow row spacings. *Canadian Journal of Plant Science* 47:597-601. https://doi.org/10.4141/cjps67-103]

[4] Fischer RA, Moreno Ramos OH, Ortiz Monasterio I, Sayre KD (2019) Yield response to plant density, row spacing and raised beds in low latitude spring wheat with ample soil resources: An update. *Field Crops Research* 232:95-105. https://doi.org/10.1016/j.fcr.2018.12.011

Effects of planting pattern on crop growth

Photos taken overwinter showed greater soil coverage by the precision-planted crop than the drilled crops (Figure 1). By May, light interception was significantly higher for the precision-planted crop than for the three drilled treatments (Table 1) and assessments of NDVI (Normalised Difference Vegetation Index, a spectral reflectance index indicating canopy size and greenness) showed a similar trend for lowest values in the wide rows and highest in the precision-planted treatment. However, green canopy coverage data was very similar between treatments. The precision-planted crop had fully compensated for its lower seed rate, but any remaining differences between treatments in canopy size and structure were small.

TABLE 1. EFFECTS OF PLANTING PATTERN ON LIGHT INTERCEPTION, CANOPY COVERAGE, NDVI (NORMALISED DIFFERENCE VEGETATION INDEX, A SPECTRAL REFLECTANCE INDEX INDICATING CANOPY SIZE/GREENNESS) AND DISEASE SEVERITY (NIAB DATA).

	NDVI 04 May	NDVI 07 June	Light interception (%) 25 May	Green canopy coverage (%) 25 May	Green canopy coverage (%) 10 July	Septoria (%) 30 May
25 cm rows	0.749	0.784	97.1	81.2	24.4	8.5
12.5 cm rows	0.762	0.796	97.0	82.3	24.8	9.3
Cross-drilled	0.766	0.793	96.6	87.0	18.1	7.0
Precision-planted	0.774	0.798	97.9	83.0	22.3	5.8
F pr.	0.250	0.646	0.026	0.361	0.395	0.343
LSD (least significant difference)	0.024	0.023	0.82	7.3	9.3	4.4

Suggestions within the industry that wide rows reduce disease pressure by limiting spread between rows were not supported by crop assessments, which showed no significant differences between treatments in Septoria severity on upper leaves (Table 1), while disease severity on lower leaves appeared higher in wide rows than the precision-planted treatment (Figure 2).

It was not possible to assess the effects of planting pattern on weed numbers, as there were no weeds in the trial area. Our expectation is that the gaps between wide rows would allow greater weed germination and growth in both autumn and spring than other planting patterns, because it takes longer before the canopy closes to shade weeds.

FIGURE 2. 25CM WIDE ROWS (LEFT) AND EQUALLY SPACED PRECISION-PLANTED CROP (RIGHT) IN MAY.

Yield benefits from precision planting

Precision planting delivered a yield benefit of 0.95 t/ha over the average of the three drilled treatments, which were not significantly different from each other. This yield benefit resulted from an increased number of grains per ear, rather than any increase in ear numbers at harvest or grain size (Table 2).

TABLE 2. EFFECTS OF PLANTING PATTERN ON YIELD, BIOMASS AND YIELD COMPONENTS (YEN DATA).

	Yield (t/ha at 85% DM)	Stem length (cm)	Total biomass (t/ha)	Ears /m^2	Grains /ear	TGW (g)	Grain moisture (%)	Specific weight (kg/hl)
25 cm rows	13.62	64.7	21.34	613	46.6	47.8	14.7	74.1
12.5 cm rows	13.29	63.2	20.49	585	47.3	48.8	14.7	74.3
Cross-drilled	13.47	63.3	20.95	585	49.3	46.8	14.9	74.2
Precision-planted	14.41	61.5	22.32	558	60.4	44.0	15.0	73.8
F pr.	0.044	0.186	0.055	0.610	0.073	0.288	0.055	0.471
LSD	0.78	3.03	0.572	89.8	11.4	5.455	0.2305	0.668

The precision-planted crop also tended to be 2-3 cm shorter than the drilled treatments (although not a statistically significant effect), suggesting reduced intra-plant competition for light. There was some lodging in the wide rows (Figure 3Figure 3. 25cm wide rows (left) and equally spaced precision-planted crop (right) at harvest, showing differences in lodging.), despite use of a variety with a low lodging risk and robust PGR programme, and the farmer observed that from ear emergence the wide rows felt 'wispy' while the precision-planted crop was visibly shorter with a firmer, stiffer feel. A trend for higher grain moisture in the precision-planted treatment suggests slightly later senescence, although this was not supported by any difference in NDVI at mid-July (data not shown).

FIGURE 3. 25CM WIDE ROWS (LEFT) AND EQUALLY SPACED PRECISION-PLANTED CROP (RIGHT) AT HARVEST, SHOWING DIFFERENCES IN LODGING.

Grain from the 25cm wide rows had significantly higher concentrations of the major nutrients N, P, K, S and Mg than grain from most of the other treatments (Table 3). The reasons for this higher nutrient content of the grain from wide rows is unclear: it could be because nutrients from late-formed tillers which died before harvest were remobilised to the grain late in the season, because the other treatments (particularly the precision-planted) had a dilution effect caused by higher yield, or because intra-plant competition in the wide rows promoted rooting hence improved nutrient capture.

TABLE 3. EFFECTS OF PLANTING PATTERN ON GRAIN NUTRIENT CONTENT AND N OFFTAKE (YEN DATA).

	Grain N (%)	Grain P (mg/kg)	Grain K (mg/kg)	Grain S (%)	Grain Mg (mg/kg)	Grain N offtake (kg/ha)
25 cm rows	1.91	3387	4413	0.115	945	221
12.5 cm rows	1.80	3288	4266	0.105	911	204
Cross-drilled	1.77	3080	4081	0.098	865	202
Precision planted	1.76	3135	4166	0.100	893	215
F pr.	0.001	0.025	0.004	<0.001	0.056	0.029
LSD	0.061	199.7	146.8	0.0055	55.5	13.2

A precision-planted future?

In sugar beet, maize and other hybrid crops with high value seeds, precision drills are successful at equidistantly placing seeds within the row, and some manufacturers are now selling precision drills for cereals. However, for narrow row cereals, how to get the coulters close enough together and still handle the trash remain challenging, and this approach is still limited to simple row configurations. Equidistant seed spacing in all directions can be approximated by broadcasting, but control of seed depth and spacing is far from precise. In future, a robotic seed planter that can be programmed for any spatial configuration may be a feasible solution.

In the short-term, these and earlier results suggest that in choosing a drill and sowing pattern the impact of row width on yield should be a consideration, along with factors such as cultivation system, cost, etc. There is also evidence that wheat varieties differ in how they respond to planting densities and spatial arrangements, including their differential ability to form tillers[5]. Studies have also shown that wheat crops can sustain yields across a wide range of seeding rates, although the interplay of regulatory factors is still not well understood[6]. Although yield in this trial was not significantly different between the wide and narrow rows, there were indications that row spacing affected canopy structure and light capture, so yield effects may occur in some situations. Most likely, wide rows will have a negative yield impact where crops are principally light limited, but will make less difference in situations of water or nutrient limitation.

In the longer term, the machinery industry should continue to invest in the development of precision planting for cereals that moves beyond the conventional row format to create an optimum spatial arrangement of plants.

[5] Abichou M, de Solan B and Andrieu B (2019) Architectural Response of Wheat Cultivars to Row Spacing Reveals Altered Perception of Plant Density. Front. Plant Sci. 10:999. https://doi.org/10.3389/fpls.2019.00999

[6] Whaley, J. M., Sparkes, D. L., Foulkes, M. J., Spink, J. H., Semere, T., and Scott, R. K. (2000). The physiological response of winter wheat to reductions in plant density. Ann. Appl. Biol. 137, 165–177. https://doi.org/10.1111/j.1744-7348.2000.tb00048.x