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Yield Enhancement Network – Review

Wheat in 2023:
‘QED by the Top Ten’

PREFACE

The Yield Enhancement Network, or YEN, was established in 2012 to provide bespoke scientific support (evidence & ideas) for individual farms looking to increase their crops' performance, often with a support organisation who may sponsor their YEN entry.

The YEN has grown and developed since 2012 and now addresses yields, nutrition and carbon intensities of wheat, barley, oats, oilseeds, and pulse crops for hundreds of farms on both sides of the Atlantic, and in Oceania. In addition to bespoke reports benchmarking and explaining crop performance for each farm, the YEN has now generated an unparalleled database of over 6,500 crop yields with over 1 million explanatory data, describing how the best professional farmers currently grow arable crops, and how these perform.

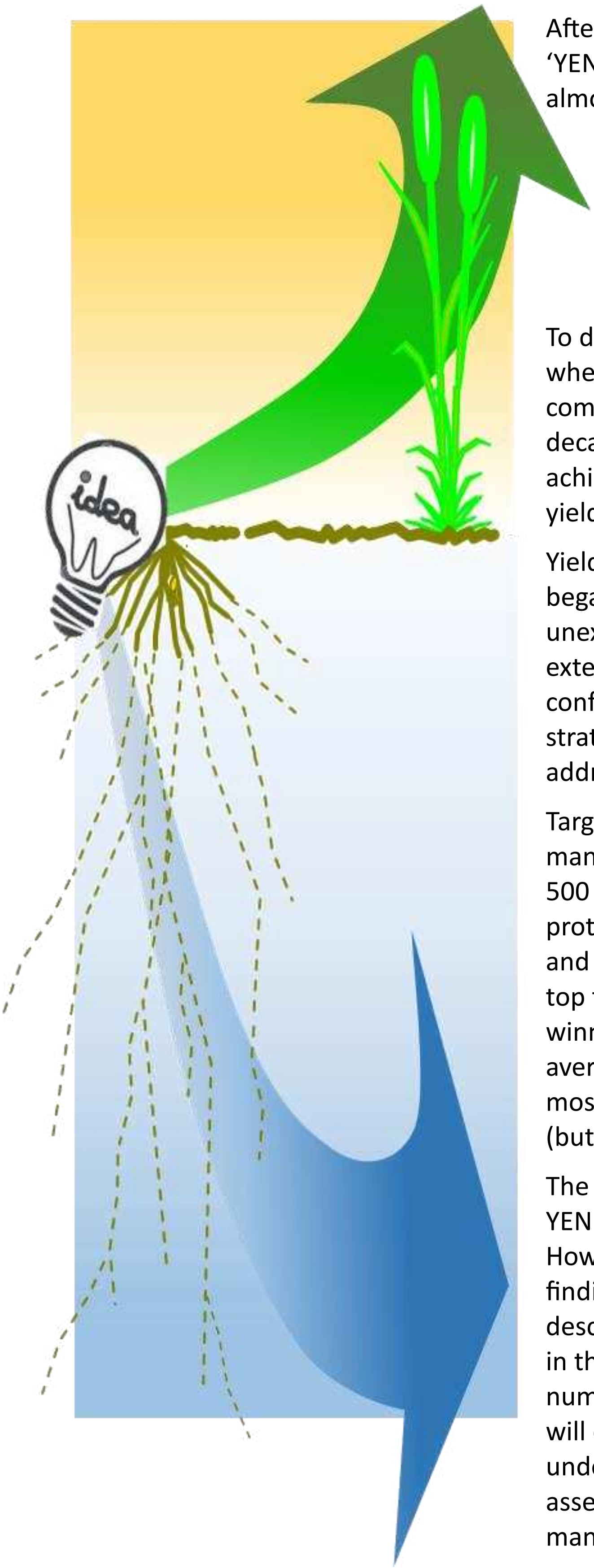
The YEN's reports have so far focused on informing individual farms about their individual crops. So now, this review seeks to demonstrate the wealth of evidence that entrants, sponsors and other stakeholders may access each season from its database, to further their quests for progress. It does so by describing how YEN wheat crops performed in 2023 compared to YEN wheat performance through the previous decade. Its focus is on the top ten crops, because these again demonstrate ('Q.E.D.') how yields may be enhanced 'by design', and thereby enable many of the aspirations of 21st century farming in the UK: better profits, and food security, with more land to spare.

This Review is provided free, so that the power of the YEN's approach – close on-farm crop monitoring with data sharing – can be demonstrated to as many potential stakeholders as possible. We welcome feed-back so that we can maximise the future value of the YEN, and improve future YEN Reviews and initiatives.

Please feed-back your views to yen@adas.co.uk.

CONTENTS

EXECUTIVE SUMMARY



After eleven years the Yield Enhancement Network or 'YEN' shows here, that yield enhancement is possible almost anywhere in the UK (probably also in NW Europe).

Through monitoring farm crops and reporting the limiting factors, the YEN provides engaged farms with bespoke evidence & ideas to support them and their support organisations in building yield enhancing strategies; they can also question all the YEN's data.

To demonstrate the full dataset's value, grain yields of all wheat entries in 2023 are reviewed here, they are compared with crop performance over the previous decade, highlighting how the ten top-yielding crops achieved an average of 14.5 t/ha in a year when all UK yields averaged only 8.1 t/ha.

Yield enhancement has not been evident since the YEN began, and average wheat yields in YEN 2023 were unexceptional at 10.7 t/ha, but data explaining the extensive yield variation in 2023 (from 5.2 to 16.6 t/ha) confirm the notion that yields can be enhanced by strategies tailored to specific farm conditions and addressing limiting factors identified in YEN reports.

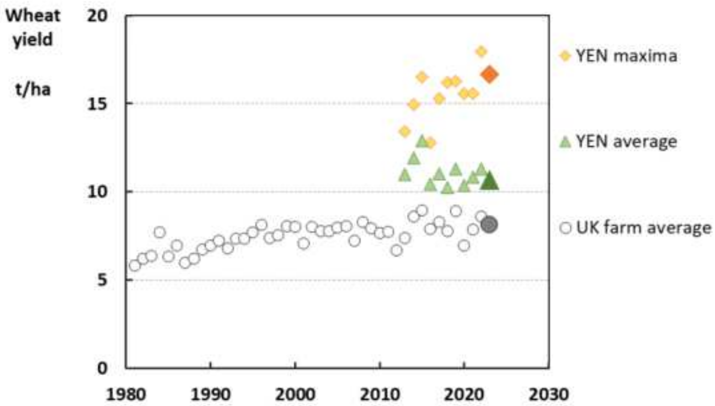
Targets to address include prolonging the growing season, managing soils to enhance rooting depth, promoting over 500 fertile shoots/m^2, providing sufficient nutrition and protection to avoid premature canopy senescence in July, and avoiding limiting grain nutrient concentrations. The top ten crops in 2023 were mostly grown by frequent YEN winners; they were sown earlier and harvested later than average, their nutrient applications were not reduced like most other YEN entries, and they received more frequent (but no more costly) fungicide applications.

The YEN now provides its participants with access to the YEN database via an on-line 'dynamic benchmarking' tool. However, for the wider industry to consider the YEN's findings, a new Wheat Growth Guide is proposed that describes an ideotype yielding 15 t/ha, which roots deep in the subsoil, has a prolonged life-span, high ear numbers and high biomass. Realisation of this ideotype will depend on enhanced farm management, hence on understanding how to make telling crop and soil assessments and how to forge new change-making crop management strategies.

INTRODUCTION

This report is on the performance of wheat entries in the UK-based YEN for harvest 2023 – the first harvest of the YEN's *second* decade; so 2023 yields here are compared to UK performance from 2013-2022, and to longer term trends where data are available. However, the YEN exists because data describing on-farm crop yields and their variation were previously deemed inadequate (Knight *et al*, 2012), so the YEN's own data are the main reference for wheat performance in 2023.

Fig. 1   Average farm wheat yields as reported by Defra since 1981 with average and maximum wheat yields in the YEN. The trend for YEN maxima is significantly positive (P=0.02) at 0.29 t/ha/year.



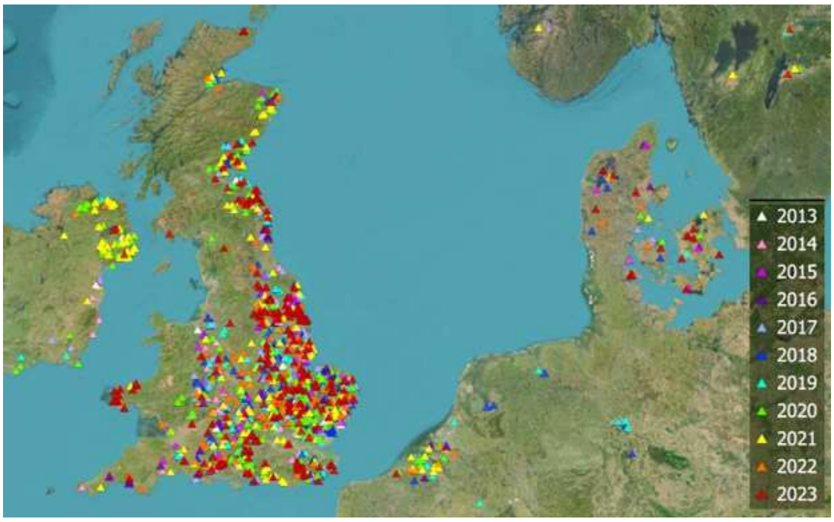
YEN wheat yields have averaged about 3 t/ha more than all UK farms (Defra statistics), and showed similar seasonal variation (Fig.1), but with no apparent change through the latest decade. The wide range of YEN yields and the extensive explanatory potential of its data, provide the value of the YEN's database; annual YEN reports to individual farms provide bespoke analyses of limiting factors for each crop. This report now seeks to draw general conclusions for 2023, on characteristics of the season, but particularly on the extensive yield variation that has occurred every year, and on how the high yields are best explained and valued.

Average farm yields from Defra statistics show more inter-seasonal variability in the recent decade than previously, but they cannot be related directly to farms' conditions or husbandry decisions. Defra only reports within season variation by region; we believe that the YEN dataset is the only region-wide dataset available to explore and formulate more sophisticated explanations of the substantial and persistent intra-seasonal variation in crop performance.

YEN ENTRIES & the Top Ten:

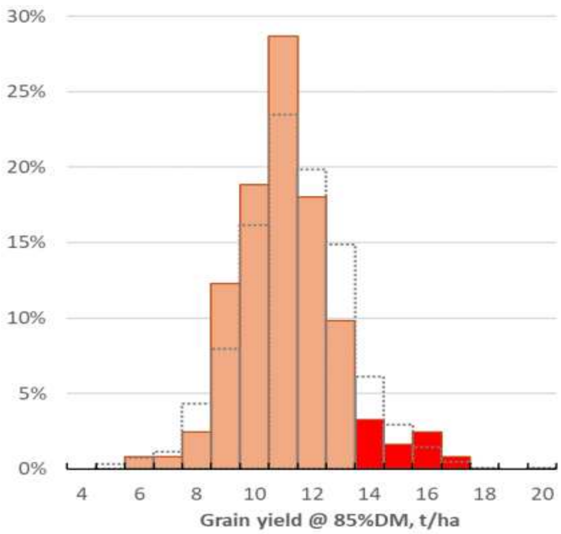
Farms completed 111 wheat entries in YEN 2023, along with 28 of barley and 12 of oats. Wheat entries were from all parts of the UK and included 12 from across Europe. The decrease in total entries from earlier years is attributed to the YEN's more demanding data entry processes in 2023 (now resolved), and can be considered unrelated to crop performance levels; the reference data from 2013 to 2022 arose from 1,521 entries which had similar wide distribution (Fig. 2).

Fig. 2 Geographic distribution of sites entering wheat crops in 2023 (red) and each year of the YEN since 2013. A few crops in the Shetlands, Finland, Estonia, France, Switzerland and New Zealand are omitted.



Yields in 2023 were from an average field area of 11.5 ha (range 0.8 to 83 ha); 33 were validated by weighbridge, the rest were unvalidated or from combine yield monitors. Sponsored tramline trials provided 35 yields. YEN wheat yields in 2023 averaged 10.7 t/ha, 3% less than the YEN's long-term average, and varied between 5.2 and 16.6 t/ha (Fig. 3), with an inter-quartile range (IQR) of 2.0 t/ha and a coefficient of variation (CV) of 17%. *Maximum* YEN wheat yields increased by ~3 t/ha through its first decade (Fig. 1) and the 2023 maximum was 16.6 t/ha, in keeping with this trend. Note that the maximum YEN yield of 18.0 t/ha in 2022 is the current world record commercial wheat yield.

Fig. 3 Frequencies of 122 wheat yields in 2023 (orange) compared to frequencies of 1,230 yields from 2013 to 2022 (dotted line). The top ten high yielding crops (>13 t/ha) are highlighted red and mapped in Fig. 4.



Yield variation of wheat crops entered in the YEN in 2023 was similar to average variation across the ten previous seasons (CV 15%; Fig. 3). Also, as in previous seasons, the top ten high wheat yields in 2023 were distributed widely across UK and included two in Denmark (Fig. 4), supporting the conclusion that high yields are possible almost everywhere. This report examines the yield variation by comparing the ten crops yielding more than 13 t/ha with all wheat crops entered in YEN in 2023.

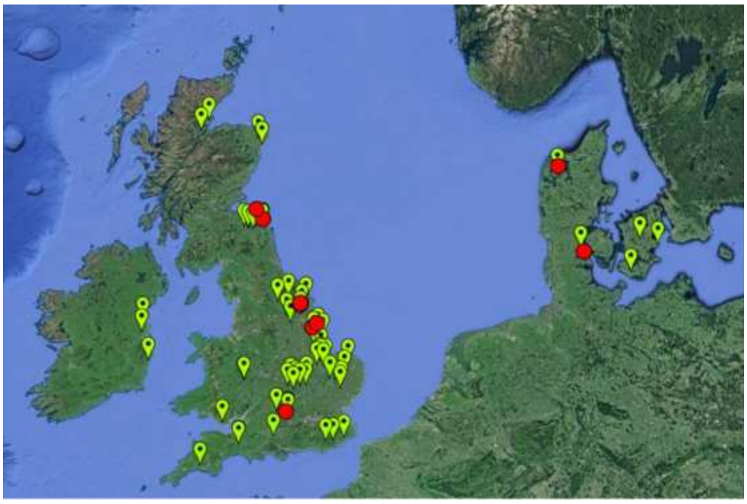
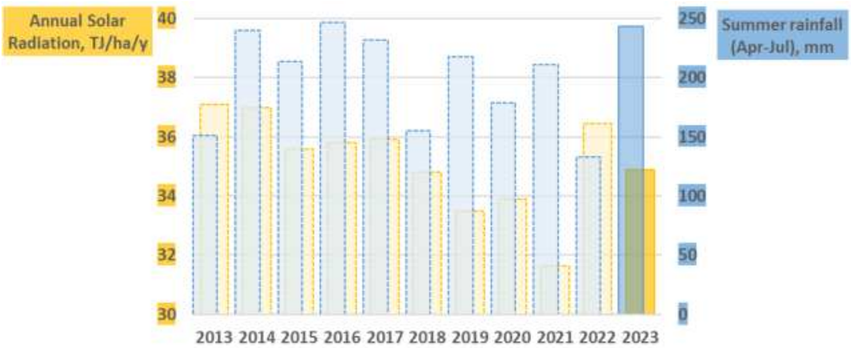


Fig. 4 Distribution of wheat crops yielding more than 14 t/ha in YEN from 2013-2022 (green points) and the ten crops yielding 13 t/ha or more (av. 14.5 t/ha) in 2023 (red points).

NATURAL RESOURCES

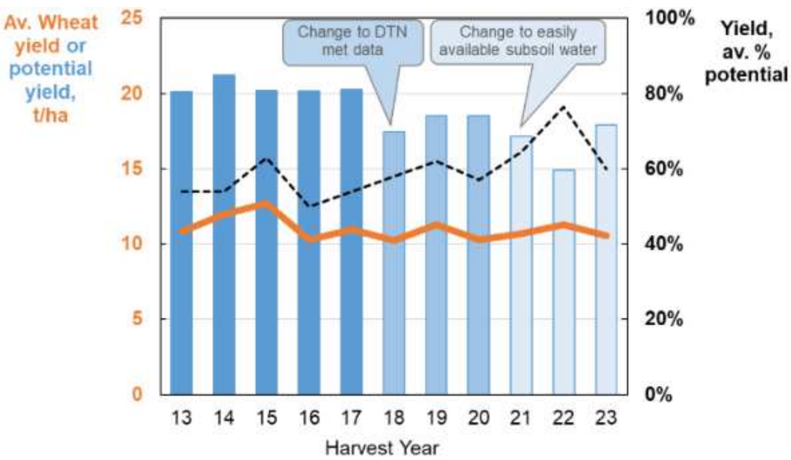
Annual incident solar radiation in the 2022-3 growing season was 34.9 TJ/ha (CV 7%), close to the average for the YEN's first decade (Fig. 5). Summer rainfall (April to July) averaged at 233 mm (CV 25%), 20% more than the 1st decade average and soil available water (SAW) averaged 208 mm (CV 36%), similar to recent years. SAW in 2023 varied hugely as usual, ranging from only 51 mm (a shallow sandy clay loam) to 429 mm (a deep fine silt).

Fig. 5 Total annual solar radiation and annual rainfall from April to July for the duration of the YEN, 2013-2023.



Together these resources created an average biophysical potential grain yield in 2023 of 18.2 t/ha (CV 13%), a little less than in recent years (taking into account that we have changed the way we estimated potential yield in that time; Fig. 6). Average potential grain yield for the Top Ten crops was very similar at 18.6 t/ha.

Fig. 6 Average wheat yields in the YEN (orange line), average estimated potential wheat yields from 2013 to 2023 (blue bars) and thus the average % of potential yield (black line, RH axis). Note that the data used and the way they were used to estimate potential yields changed through this period so improvement in %YP should be inferred.



The Weather

The growing season in 2022-3 was warmer than ever (Fig. 7), and was characterised by a warm and moist autumn, a dry February, wet March, dry May and bright June, with June sometimes being hot, followed by a dull and moist July (Fig. 7).

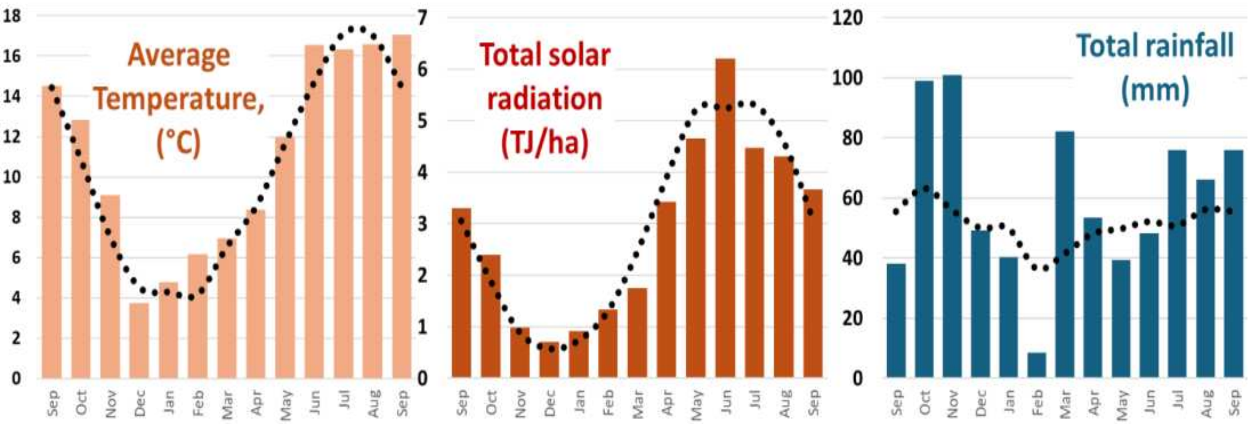


Fig. 7 Monthly average temperature, solar radiation and rainfall for an example location in central England through the 2022-2023 growing season, with long-term averages (dotted lines).

CROP MANAGEMENT & GROWING CONDITIONS

Most YEN wheat crops were established after break crops (Fig.8) on land that had nil or infrequent organic manure applications (Fig. 9). The early harvest in 2022 and warm and moist autumn generally allowed timely drilling and good establishment. The median date of sowing was 29th September (range: 30 Aug to 21 Feb; IQR 20 days). No Top Ten crop was sown in spring; the latest was sown on 11th November.

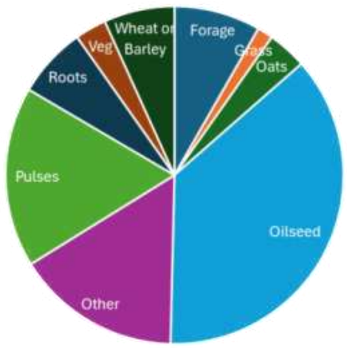


Fig. 8. Distribution of crop types grown before YEN wheat crops harvested in 2023.

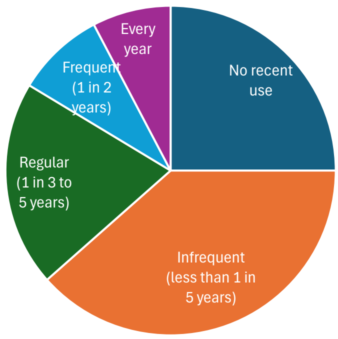


Fig. 9. Distribution of Organic Manures applied previous to YEN wheat fields entered in 2023.

Thirty recently bred varieties were represented; most were from Group 4 (Fig. 10) and were recently released (first listed in the last 5 years; Fig. 12). Most were of average maturity; only 10% were a day or two later than average maturity (Fig. 11). Favoured varieties generally had their normal grain protein levels just exceeding 11% (Fig. 13). The nine growers of the Top Ten crops chose six different varieties; four chose Champion.

To summarise growing conditions in 2022-3, after good establishment, a wet November and cold December inhibited early tillering and root development, especially on heavy and poorly drained land. Despite early drilling with pre-emergence herbicide use, weeds took advantage of some patchy crops and multiple 'post-ems' were often needed. The winter was drier than average, especially February, but a wet March in most regions, especially the midlands and south, negated expectations of good soil nutrient retention and delayed spring operations. Spring rains also built high septoria pressure, giving T1 and T2 fungicides strong curative roles. But drier days then slowed septoria development so protectant fungicide activity was less challenged.

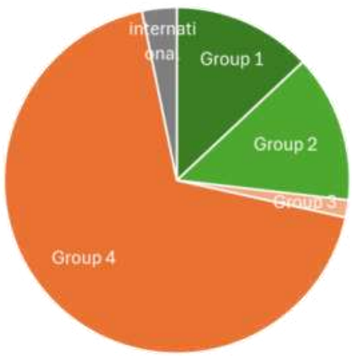


Fig. 10. Distribution of varieties by Group, for YEN wheat crops harvested in 2023.

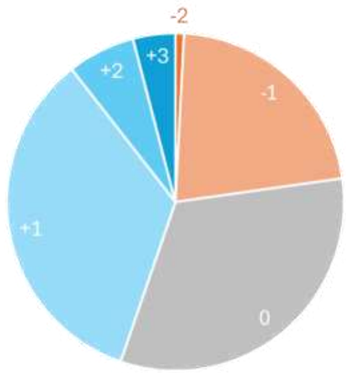


Fig. 11. Distribution of variety maturity (days compared to control), for YEN wheat crops harvested in 2023.

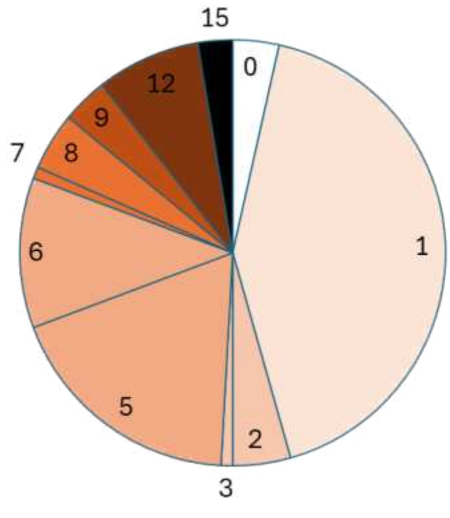


Fig. 12. Distribution of variety age (years since first listed) for YEN wheat crops harvested in 2023.

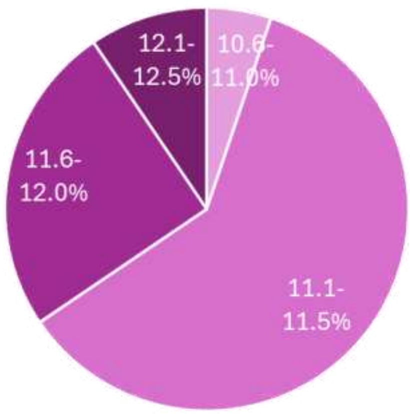


Fig. 13. Distribution of variety by normal grain protein content (%DM) for YEN wheat crops harvested in 2023.

The warm, wet spring was optimal for continued tillering and the associated lodging risk led to increased use of PGRs (Fig. 14). Cold and frosty spells had largely controlled yellow rust over winter; increased rust development was then controlled by hot June weather.

The slow decrease in overall crop protection spend seen in recent years was reversed, but the slow decline in use of fertiliser N persisted; average use only just exceeded 200 kg/ha N in 2023 (CV 23%; Fig. 14). The Top Ten crops received 17 kg/ha more N than the YEN average.

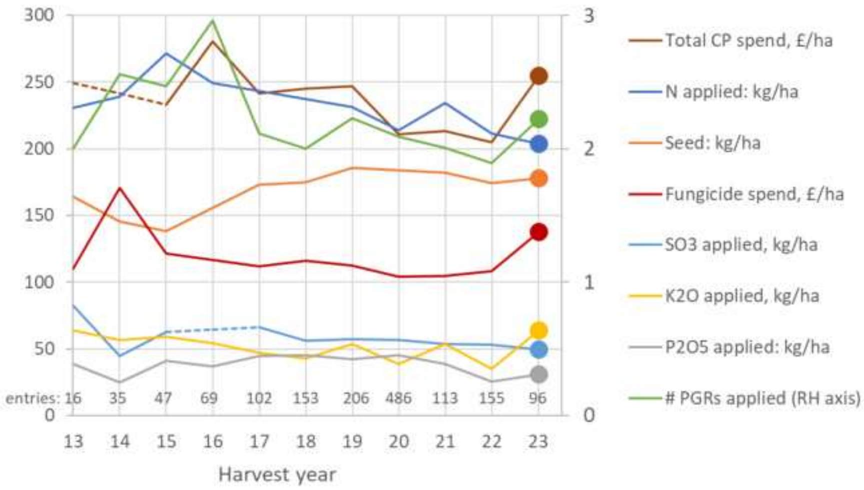


Fig. 14. Average input levels used on YEN wheat crops harvested in 2023 compared to those in the previous decade. The number of entries in each year is indicated.

A minority of wheat crops, mainly those on light or shallow soils, struggled to find adequate water for further growth and nutrient uptake in May and early June but overall surviving fertile shoot numbers were relatively high. Dense tillers with warm and dry conditions generally inhibited the success of ear development and grain set, and subsequent green canopy survival and grain filling were commonly compromised because the summer moved from being dry and warm (sometimes hot, especially in the west) to being wet and dull towards harvest. Frequent rain through late June and July tested persistence of T2 fungicides, caused much lodging and more broad-leaved weed growth than normal, prompting some late herbicide use. Yield responses to fungicides were thus smaller than expected.

CROP DEVELOPMENT AND RESOURCE CAPTURE

Overall it was the warmest year on record and, although early crop development phases show no trends over years, presumably because they are controlled by daylength, the YEN has seen a significant foreshortening of the grain filling phase (Fig. 15). Crops in 2023 were generally too advanced for the cool, dull July to delay senescence by much, so harvest was generally prompt, but followed disappointing grain filling. The Top Ten crops emerged a week earlier than average, and they senesced and were harvested a week later.

Fig. 15a. Average development pattern of wheat in 2023, compared to those through the previous decade. Average growth stage dates are at the right end of each colour bar. Average grain yields (t/ha) are on the right.

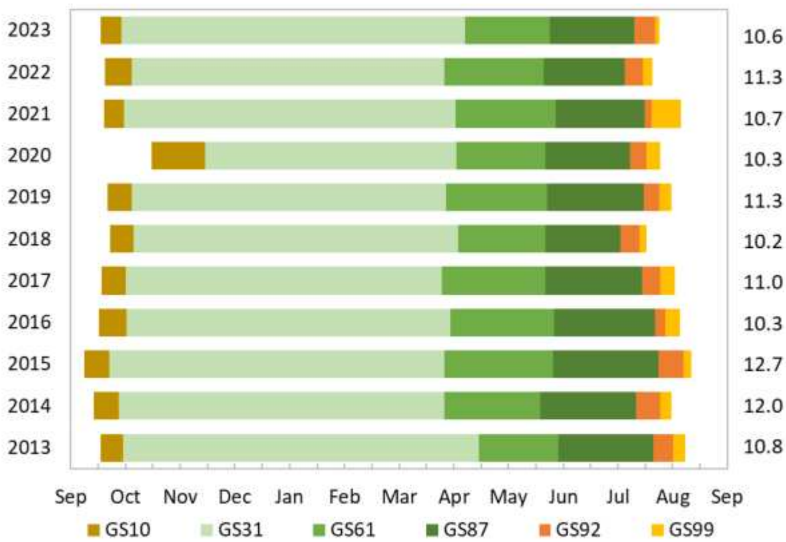
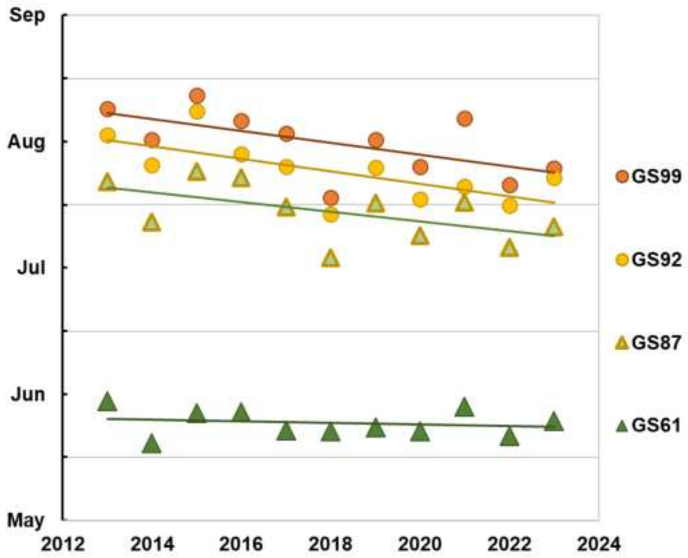
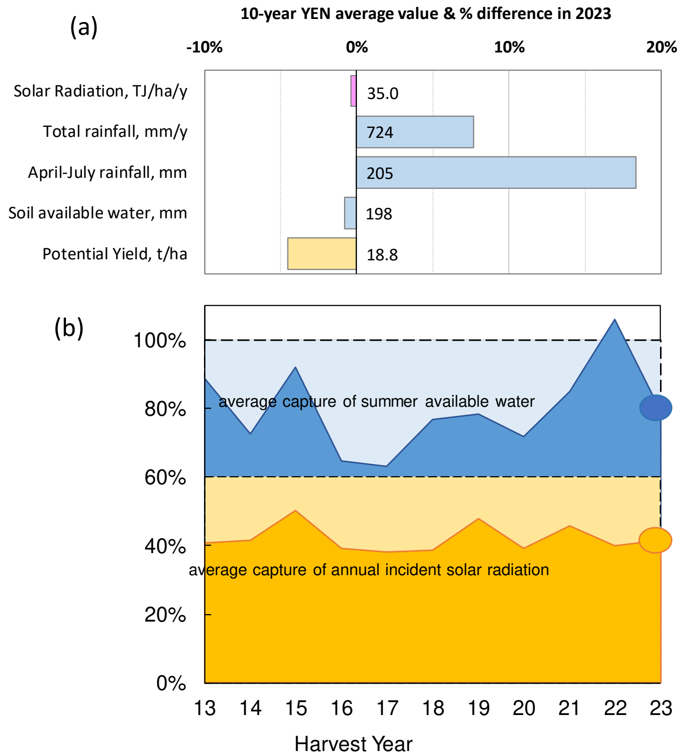


Fig. 15b. Average dates and rates of change of flowering (GS61), full senescence (GS87), maturity (GS92) and harvest ripeness (GS99) for YEN wheat crops from 2013 to 2023. The decrease in grain filling (GS61 to GS87) of 1 day per year through this decade is statistically significant at P=0.06.

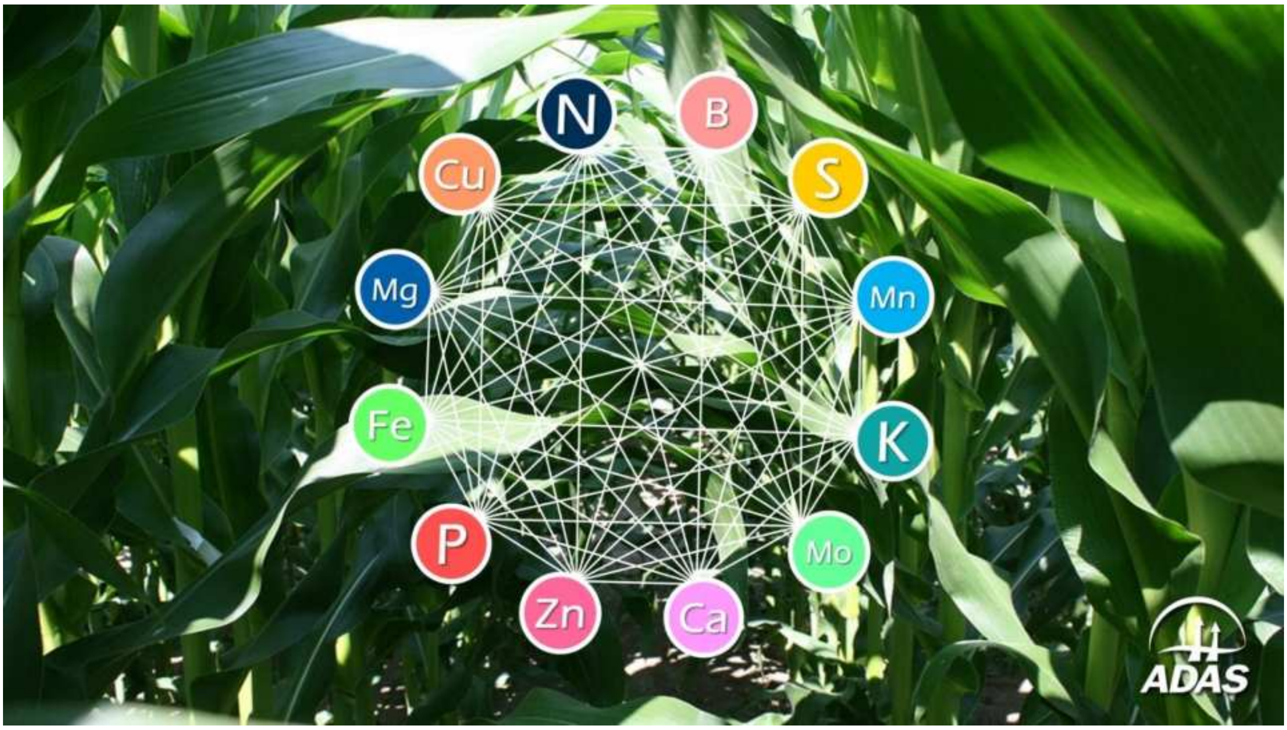


The YEN is founded on the concept that growth and yield of arable crops primarily relate to their success in capturing physical resources of light energy and water (Fig. 16a) i.e. crops can primarily be regarded as converters of solar into edible energy, with water providing the associated and essential cooling.

Fig. 16. (a) Incident physical resources for growth and (b) their average capture by wheat crops in the YEN in 2023 compared to the preceding decade. Potential yields are estimated in the YEN by assuming that any annual crop could (if managed perfectly) capture 60% of annual incident solar radiation and all of the summer available water (water held in soil to 1.5m depth or to rock at field capacity plus rainfall from April to July).



We cannot measure directly each crop's success of resource capture, but we can estimate their approximate levels achieved by assuming that 'C3' crops (C3 is the way wheat does photosynthesis, whereas C4 is the way maize and sorghum photosynthesise) in the UK currently achieve efficiencies of resource conversion that are fairly consistent at 1.2 tonnes biomass per TJ solar radiation intercepted, and 5 t/ha biomass per 100mm water captured. These assumptions indicate that YEN wheat crops have generally been achieving about 40% energy capture (CV in 2023: 18%) and 80% use of available water (CV in 2023: 27%), and that this was much the same in 2023 (Fig. 16b).



CROP NUTRITION

The YEN monitors apparent availabilities of soil nutrients and their capture in above ground crop biomass using soil, leaf and grain analysis, and the nutrient applications reported by farms (Fig. 14). Average soil nutrient availabilities were very similar in 2023 to YEN crops in previous seasons (Table 1). However, as usual, variations in nutrient availabilities between fields were large, their CVs being 49% for P, 58% for K, 72% for Mg and 40% for soil organic matter. Soils tended to be alkaline on average (Table 1; CV 9%).

Table 1 Average soil analysis from 91 fields growing wheat in the YEN in 2023 compared to 995 fields growing wheat from 2013 to 2022. Soil pH was determined in water and soil organic matter was determined by loss on ignition.

Years	Soil pH	Soil P (mg/l)	Soil K (mg/l)	Soil Mg (mg/l)	Soil OM (%)
2013-22	7.20	27.7	193	119	5.40
2023	7.18	27.4	174	102	5.06

Leaf tissue analyses

Leaf samples were analysed at two growth stages (GS31 & GS39) in 2023 compared to four stages in previous years of the YEN, and they omitted nitrogen. Despite the spring weather which created dry topsoils and must have inhibited nutrient capture, other leaf macro-nutrient concentrations were very similar or a little greater than in previous seasons, and most micro-nutrients were similar also, with only iron showing greater levels than previously (Fig. 17).

Whilst there is some uncertainty in the industry about the reliability of leaf analysis in pinpointing crop needs for nutritional adjustments, the long-term averages in Fig.18 appear to remain relatively stable and although they change somewhat between growth stages nutrients tend to change in a consistent way, so it will be useful to refer to these graphs in future, when interpreting leaf analysis results.

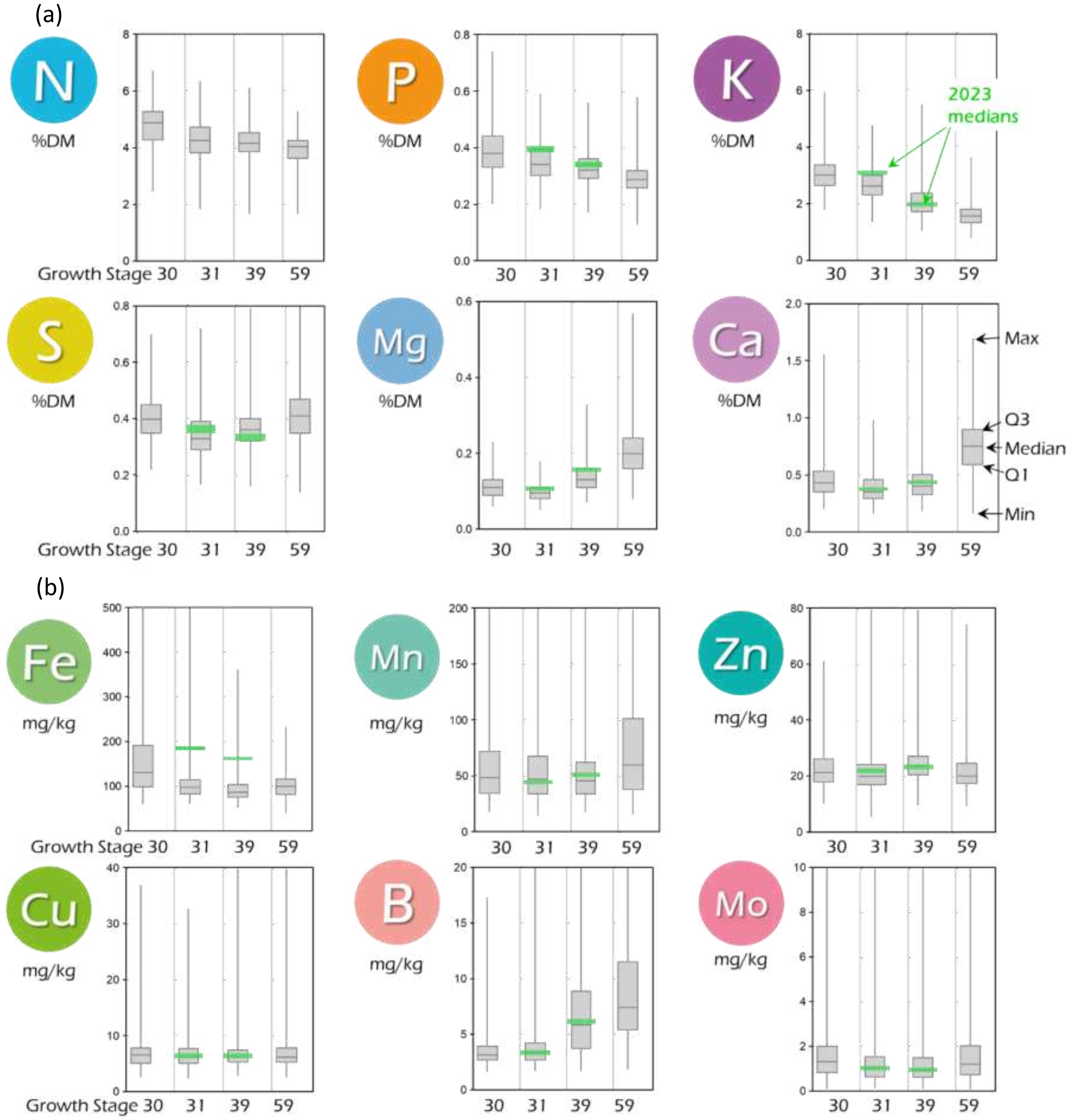


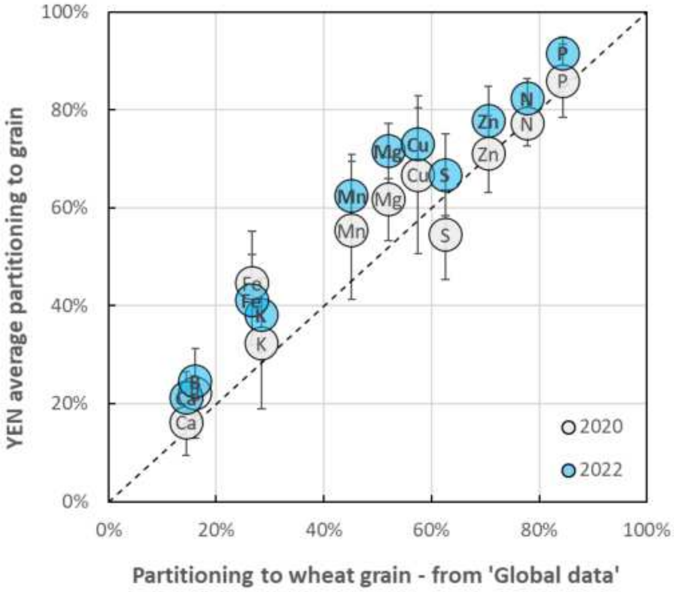
Fig. 17. Green bars show median concentrations of (a) macro-nutrients (%DM) and (b) micro-nutrients (mg/kg DM) in youngest fully expanded leaves of 67 wheat crops at GS31 and GS39 in 2023 compared the variation found in >200 crops grown from 2019 to 2022. Q3 = upper quartile; Q1 = lower quartile. Symbols for the nutrient elements are defined in Fig.16.

Harvest analyses

YEN data have shown that, for most nutrients, (i) the majority of crop capture becomes concentrated in the grain by harvest, (ii) grain nutrient concentrations vary by as much or more than yield varies, and (iii) partitioning of nutrients between grain and straw varies hugely between nutrients but is relatively consistent for each nutrient (Fig. 18).

Thus YEN has shown that yield measurements and grain analyses together can provide good assessments of (i) the removals of all nutrients by any crop from the soil, thus (ii) the soil balance between inputs and removals plus (iii) the efficiencies of the inputs used, and, by referring to 'critical' grain nutrient concentrations (iv) the sufficiency with which each crop captured each nutrient[1]. Hence harvest analysis is now being seen as the essential tool whereby crop managers can manage crop nutrition 'by results'. YEN has thus developed a service (YEN Nutrition) and a Thematic Network (NUTRI-CHECK NET) to disseminate this discovery.

Fig. 18 Partitioning of nutrients between grain and straw at harvest for wheat crops grown by 32 YEN entrants in 2020 and 93 YEN entrants in 2022 compared with 'global' data derived from feedipedia.com (and the Wheat Growth Guide). Symbols for the nutrient elements are defined in Fig.16. Error bars show ±1 SD. These data were funded by Anglo American.



Grain protein levels (hence N and S) were low in 2023 compared to their long term medians (Fig. 19). This is associated with lower use of fertiliser N, and corroborates results for 2023 from the British Survey of Fertilizer Practice and the AHDB Cereal Quality Survey. Other grain nutrients, particularly phosphorus, calcium, iron, zinc and boron have also shown trends of decreasing concentrations over recent years and were low in 2023, whist levels of other macro-nutrients (potassium, magnesium and manganese) were similar to average.

For eight nutrients (N, P, K, S, Mg, Mn, Zn & Cu), their concentrations in the grain dry matter can be used to judge the adequacy of their uptake by the crop by comparing values with known published critical values (Fig.19)[1]. Grain protein concentrations (= N% x 5.7) can also be compared to values published for each variety in the AHDB Recommended List to judge whether N uptake was in excess of requirements for yield.

The overall frequencies of nutritional errors in 2023 (Fig. 20) were similar to the frequencies seen in previous years of YEN. Whilst low grain P was again much the most frequent error (83% of crops), the most notable difference in individual errors in 2023 was inadequate uptake of N and S; 49% of crops in 2023 fell more than 1% below the grain protein content listed for their variety on the RL (equivalent to an error in fertiliser N use of ~50 kg/ha) whereas in the longer term dataset only 20% of crops showed this degree of inadequate N uptake.

1 Sylvester-Bradley, R., Roques, S., Baxter, C. & Kendall, S. (2022). Nutrient harvests: the essential yardstick to transform crop nutrition. *Proceedings of the International Fertiliser Society* **874**, 2-56.

Fig. 19. Differences in average grain concentrations of macro- and micro-nutrients in 2023 and preceding years from the current norms (av. 2017-23) which are quoted beside each origin.

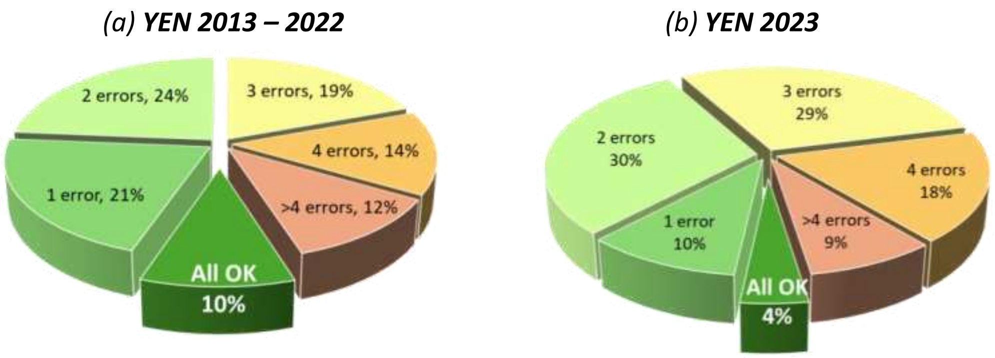
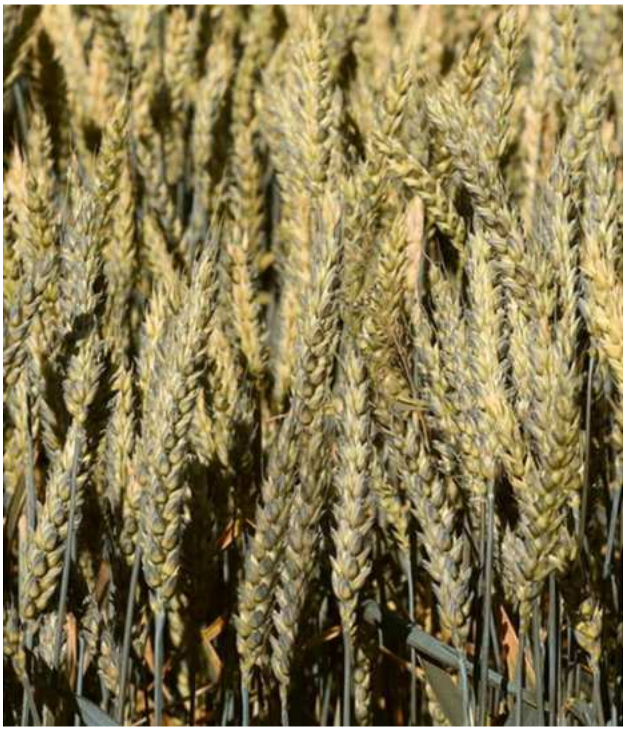


Fig. 20 Frequency or nutritional 'errors' indicated by 117 grain analyses in 2023 (b) compared to (a) error frequencies of 913 YEN wheat crops in 2013 to 2022. Errors are defined here as grain protein differing by >1% from the variety's norm in AHDB's RL, or nutrient concentrations being less than 0.32%P, 0.38%K, 0.12%S, 0.08%Mg, 20 ppm Mn, 15 ppm Zn or 3 ppm Cu.

YIELD FORMATION



The YEN employs the analysis and explanation of wheat yields set out in the Wheat Growth Guide, where crops are considered to grow and mature through successive phases of:

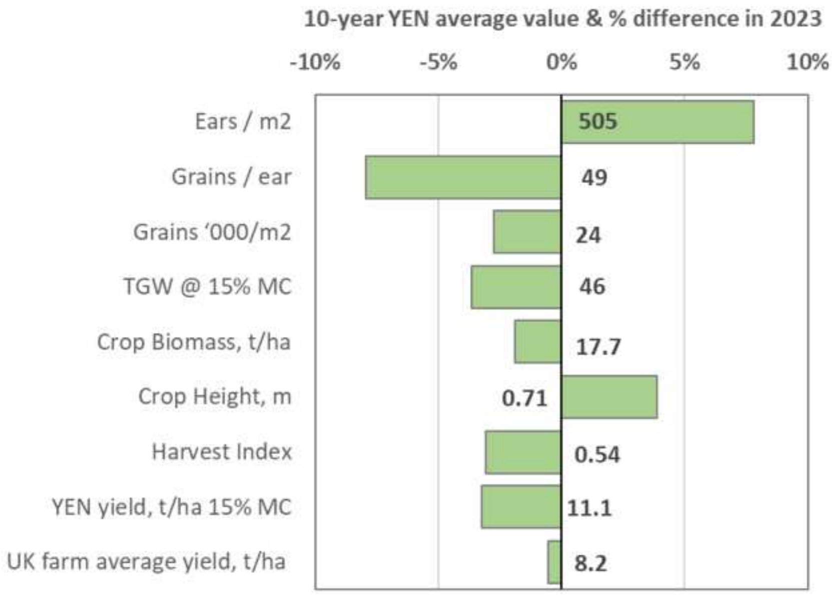
1. **Foundation**, determining the root system's framework and potential shoot numbers, then
2. **Construction**, determining ear number, stem height and stem reserves, yield-forming leaves and canopy size, ear size and fertility, and then
3. **Production**, determining the sizes, weights, densities and contents of grains, hence the yield and quality of the harvested grain.

The success of each phase is determined by captured quantities of the biophysical resources needed for photosynthesis: light energy, water and nutrients, as described in the sections above.

Warm and moist conditions in winter and spring of 2022-3, and the relatively late start of stem extension, enabled good plant establishment and tillering leading to denser crop stands with 8% more ears and 3 cm taller than average (Fig. 21). Lodging risk and prevalence were thus greater than normal whilst dry May and June conditions and reduced applications of fertiliser N restricted crops from fulfilling their early promise.

Average grain set (no. per ear) was down 8% and grains/m^2 was reduced by 3% from the 10-year average. Then grain filling was foreshortened and reduced by warm conditions and a dull July so that thousand grain weight (TGW), harvest index, grain yield and crop biomass were all reduced by 2-4% compared to the 10-year average (Fig. 21).

Fig. 21 Average values (text) for yield and components of yield for YEN wheat crops from 2013 to 2022 and % differences from these in 2023. UK farm average yields are from Defra statistics.



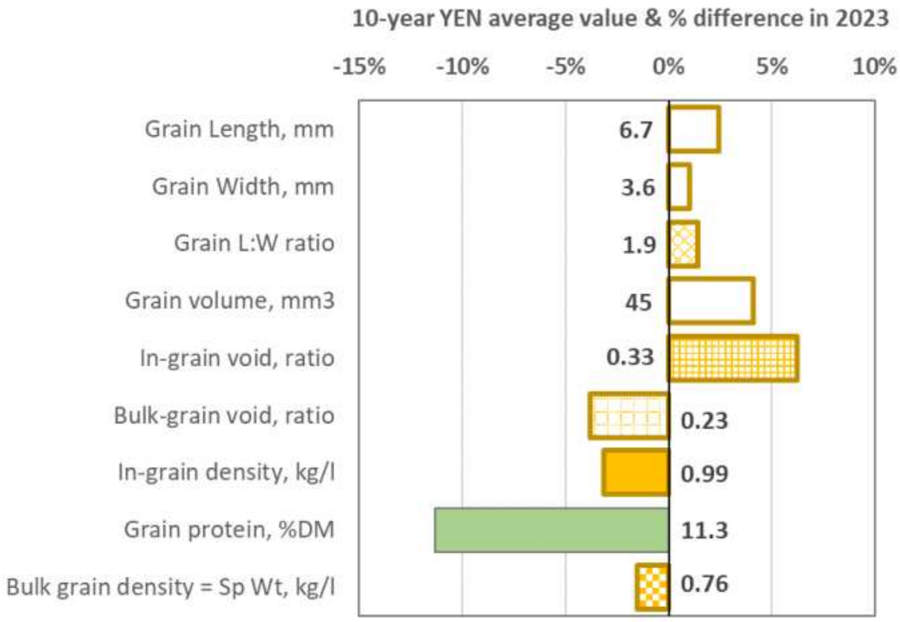
Grain Density and Quality

Since 2016 the YEN has measured average lengths and widths of individual grains in order to estimate (i) grain storage capacity (often dubbed 'sink'), (ii) whether yield was limited by sink size or by assimilate supply (dubbed 'source'), and then (iii) how specific weight (i.e. bulk grain density) was determined.

With grain numbers (/m^2) being slightly less than average in 2023, grain lengths were increased in compensation. Grain lengths are determined early in grain-filling when grain cell division is complete and grain cells grow due mostly to water uptake; this water is subsequently replaced by assimilates, mostly starch from concurrent photosynthesis (evident as grains progress through their so-called watery, milky, cheesy and doughy stages). Thus grain lengths are taken to indicate grain sink capacities, whilst final grain widths are taken to reflect assimilate supplies.

Grain widths did not increase proportionately so grain length to width ratio was greater than normal (Fig. 22), TGW was 4% less than normal (Fig. 21), grain density was reduced and in-grain void (recognizable as grain shriveling) was increased. The worse specific weights than normal were thus associated with grain formation being limited by supplies of assimilates, both protein (less N was redistributed from the canopy to grain) and *de novo* starch supplies from photosynthesis – i.e. wheat crops in 2023 tended to be 'source limited'.

Fig. 22 Average values (text) for grain density and quality for YEN wheat crops from 2013 to 2022 and % differences from these in 2023.



As with all wheats, grain protein contents of Group 1 varieties entered in the YEN 2023 milling wheat quality competition were low compared to the long-term average (Fig. 22). However, the top ten entries (based on protein yield, specific weight and Hagberg falling number) generally had strong protein giving very good milling performance and loaf quality with a fine and white breadcrumb. The three award winners in 2023 all grew Crusoe, the variety that has won all but one gold award in YEN quality competitions since 2018. The crop awarded gold for quality also achieved a yield of 11.9 t/ha, proving that high yields and high milling quality can both be achieved together.

Yield variation in 2023 & Top Ten performance

Wheat yields varied similarly in 2023 (CV 17%) to the extent that they have varied in all previous YEN seasons (average CV 15%). Probably the key factor accounting for yield variation in 2023 was crop longevity – involving both earlier emergence and later senescence, so later harvests. Those crops senescing later apparently had better water availability and nutrition. The few crops sown very late (December to February) yielded poorly, despite being sown at high seed rates. Yields have been related inversely to seed rate in the past, probably because late sowing cannot be fully counteracted by increasing seed rate.

Yields related positively to the soil's capacity to hold available water and the Top Ten crops had 19mm more available water than the average, enough to grow an extra tonne of biomass per ha. As explained above, grain-filling was particularly important in determining yields with the generally short production phase and dull July in 2023; each extra 0.25mm of average final grain width was associated with an extra t/ha grain yield, and TGW was the yield component best related to final grain yields; TGW of the Top Ten crops was 46 g compared to the average of 44 g. However, the Top Ten crops also grew 180 more ears/m^2 than the average crop with the same grains/ear of 43, so set 7,800 more grains/m^2, and these produced an extra 4.7 t/ha biomass, so harvest index was 56% compared to the average of 52%.

The Top Ten crops found 79 kg/ha more N to store in their grain compared to the 2023 average of 157 kg/ha. Crops receiving 150 kg/ha or less fertiliser N tended to yield worse than crops receiving 200 kg/ha N or more, and the Top Ten received 17 kg/ha more than average. Although the spend on fungicides did not relate significantly to yield in 2023, crops with 4 or more fungicide applications yielded better than crops receiving 3 or less, suggesting that these growers responded more astutely to the increased disease threats. No grain nutrient concentration was positively associated with grain yield, suggesting that none of the nutrition 'errors' described above were over-riding in determining yield variation. Nutrients in the Top Ten grain samples generally had slightly smaller concentrations than average, except for iron and boron.

DISCUSSION

As it starts its second decade, the YEN continues to develop and change. Through its comprehensive crop reports the YEN has now informed hundreds of farms of factors limiting their crops' performance and has shown how farms differ consistently in these. Of course, farms are subject to strong uncontrollable forces, primarily the weather. However, the YEN's data clearly show what most advisors and other farm supporters learn, that farms differ significantly in factors that can be changed – such as their strategies for soil management, crop establishment, crop protection, and particularly crop nutrition. These factors can potentially enhance performance, if they can be measured, identified as limiting, and then changed. In addition, the YEN data are now showing what appears to be a new industry-wide challenge to mitigate the climatic trend causing an undesirable foreshortening of grain filling (Fig. 15b).

The main issue governing crop nutritional performance has been a failure to recognise and correct financial losses arising from erroneous N management strategies; some farms are too generous, others are too stingy, whilst about half get it roughly right. The proportion of stingy farms increased in 2023 (Figs. 19 & 20). YEN data and the government's Survey of Fertiliser Practice show farm applications of all nutrients have been diminishing, and it appears from the trends in grain protein (Fig. 19; note that this uses Euros because this project is European) that this is likely to also be to the detriment of profitability (Fig. 23[2]).

In addition to NUTRI-CHECK NET, the YEN has spawned a series of research and extension projects to address some of the evident crop performance issues and this should probably be the way that YEN develops in future; as its database grows and deductions can be made with increasing confidence about limiting factors and how

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2 Sylvester-Bradley, R. & Clarke, S. (2009). *Using grain N% as a signature for good N use.* HGCA Project Report No. 458,

they might best be countered, wider benefits of the YEN will be seen through analysis of the database as a whole, in addition to the benefits that individual farms can derive from their bespoke reports on their own selected crops.

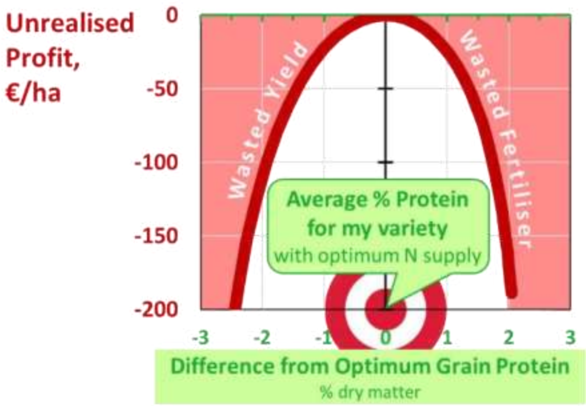

Fig. 23 Diagram derived in the EU-funded NUTRI-CHECK NET project, from standard N response curves (as used to revise RB209), to show how differences in grain protein (%DM) from a variety's norm (as given in the AHDB RL) can diagnose likely unrealized profits from inaccurate crop N management.

Undoubtedly routinely uploading farm data to the YEN has proved an onerous task for farmers, and this accounts for entries being in the tens and hundreds, rather than the thousands. But the relevance and confidence that can be drawn from YEN database analyses depend on maintaining (at least) annual engagements by farms, and on enabling quick and easy database access by data analysts. Continuing YEN investments therefore have been made to collate and curate the data, to ease data entry and to make feed-back to farms more immediate – with a 'dynamic benchmarking' tool. Meanwhile the YEN is increasing the number of crops, regions and issues that it addresses; in addition to yield enhancement and crop nutritional status, farms can now gauge and benchmark their carbon intensities, and their linseed crops, whilst regional access is extending to further provinces and states across north America and in New Zealand.

CONCLUSIONS

Reviewing the YEN after the 2023 growing season has proved telling. Overall wheat performance in 2023 was unexceptional, average yields being similar to the decadal average. However, 2023 yields were variable and have augmented the confidence underlying many deductions that were drawn from the YEN's first decade – yield variability between fields is huge, even within one season. Even though 2023, like every other season, was unique, the influence of controllable factors on yield levels has been obvious: the importance of a long growing season, the extent and continuity of moisture capture, the adequacy of nutrition especially with N, and the attention paid to crop protection. However, because farms differ, any notion that uniform solutions to yield enhancement can be identified and advocated easily, without specific farm-tailoring, appears mistaken. For example, no single variety enabled all top ten yields in 2023. We conclude that farm-tailoring must require more quantitative on-farm monitoring hence self-awareness than has been common hitherto; this is now how the YEN seeks to develop its services – easy farm-friendly assessments of the most telling explanatory metrics, leading to farm-tailored deductions and enhancements of performance.

The approach to yield enhancement arising through the YEN differs substantially from approaches advocated in the scientific literature which tend to focus far more on genetic improvement than farming decisions and on informing regional or national decision-making (e.g. the Yield Gap Atlas) rather than farm-scale decision-making. The YEN must therefore make its case by generating refereed papers in science journals that contrast the extent of farm to farm variation with the smaller variation between adapted varieties and between regions, and emphasise the need to support and extend on-farm monitoring, interpretation and change-making.

As regards the science underlying crop productivity, as represented in the Wheat Growth Guide, analysis of the YEN database suggests that a new Guide is now needed which argues, amongst other things, that high yields in NW Europe should be associated with ear number more than ear fertility and with biomass production more than harvest index, thus that the role of farm management in realising the high yielding ideotype is very important and has been the subject of insufficient research.

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YEN SPONSORS 2023

The YEN would not exist without its sponsors. Sponsors in 2023 were as follows:

LINKS & REFERENCES

AHDB Nutrient Management Guide (RB209)

AHDB Recommended Lists for cereals & oilseeds

AHDB Wheat Growth Guide

British Survey of Fertiliser Practice (2024)

NUTRI-CHECK NET Project

Yield Enhancement Network

Yield Gap Atlas

Dimbleby, H. (2022). *National Food Strategy. The Plan.* Access here.

Knight, S., Kightley, S., Bingham, I., Hoad, S., Lang, B., Philpott, H., Stobart, R., Thomas, J., Barnes, A. & Ball, B. (2012). *Desk study to evaluate contributory causes of the current 'yield plateau' in wheat and oilseed rape.* AHDB Project Report No. 502