FIG Report: Crop Momentum 2019

FIG members

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The Concept & Hypothesis

The idea of 'crop momentum' arose because (a) YEN entrants' data over five seasons had shown that greater yields were associated with greater frequency applying inputs, or 'attention to detail', and (b) crop growth might result from two interdependent processes – assimilating 'source' materials through photosynthesis, and creating a 'sink' to utilise the source, mainly through cell / tissue expansion. It was proposed that an inadequate sink might feedback to inhibit source assimilation, consequently the sink at the next stage could be affected by the source at the current stage. Thus the initial source may affect the sink for the next stage; so our idea was that successive stimulation of growth might enhance subsequent growth, creating 'momentum' in the longer term.

Plants must often cope with adverse or constraining environmental conditions (stress) and the effect of sub-optimal conditions (e.g. drought or nutrient stress) will tend to reduce source and / or sink, and thus longer-term momentum. So, the notion to be tested here was of using commonly available crop health information to recognise, and then try to overcome, any impending stresses.

Unlike conventional trials this FIG decided to test combinations of several treatments that together might be deemed to represent 'attention to detail'. Thus participants accepted that they would not be able to identify specific effects of single treatments.

The Approach

Farmers in the group needed to monitor crops frequently, so made full use of tissue analysis and (if available) grain nutrient benchmarking results from previous YEN competition reports. Farmers then aimed to maintain adequate levels (as near as possible) of crop resources throughout the growing season, by protecting against adverse conditions. ADAS crop physiologists provided the farmers with an *á la carte* menu of options to monitor crop status and then husbandry options aimed at alleviating stresses (biotic and abiotic) hence promoting crop momentum (Table 1). Farmers made their own decisions on which products to apply and at what timings. Treatment options adopted included foliar sprays (particularly micro-nutrients and phosphites) and biostimulants, often on a little and often basis (Table 3).

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Each farmer set up a tramline trial in winter wheat to test their combined treatments, based on a design discussed with the ADAS facilitator. The trial design was carefully considered to ensure practicality for the farmer applying the treatments and harvesting the area, but also to ensure that reliable results were obtained. This included trying where possible to include replication of treatments, and randomization of treatments within the field. Time was also spent selecting fields which would reduce the risk of comparisons being confounded with underlying variation. Trial sites covered a wide geographic area and range of soil types.

One of the most interesting aspects of this FIG was to see the different approaches adopted by individual farmers. These ranged from single product applications to a 'kitchen sink' policy of applying multiple products at multiple timings (Table 3).

Table 1: Monthly Momentum Management Menu suggesting both Monitoring Targets and Husbandry Options which could be considered compatible with yields of 16 t/ha.

Month	**Monitoring Targets**	**Husbandry Options**
August	Check for good rooting by the previous crop, and lack of a cultivation 'pan' 1 deep burrowing worm / m^2	Choose high-yielding field after a disease break, with low blackgrass risk, good residual N and P & K indices >=2. Choose a later maturing variety (and prefer low protein, not short, with erect flag leaves) … or maybe a hybrid?
September	Fertile seedbed with no pan 50% plant emergence by ~30th Sept.	Apply slurry or digestate Sow late Sept (or mid Sept if in north) Avoid wide row spacing
October	150-200 plants / m^2 established, roots reaching 0.3 m & tillering starting	Apply biostimulant or phosphite to encourage rooting. Consider phosphate, manganese, zinc and / or copper sprays.
November	Roots reaching 0.5 m, and plants with 4 mainstem leaves & 1-3 shoots – these will be the yield-bearing shoots. No leaf death.	Leaf sample for multi-nutrient analysis, and foliar sprays accordingly
December	Roots reaching 0.6 m, and plants with 5 mainstem leaves & >4 shoots – further shoots will not yield; maybe oldest (seminal) leaf senescing. GAI=0.3 (10% ground-cover)	Biostimulants, Phosphites
January	Roots reaching 0.7 m, 6th mainstem leaf appearing & >4 shoots – maybe 2 oldest leaves dead. GAI=0.5 (20% ground-cover)	Leaf sample for multi-nutrient analysis, and foliar sprays accordingly in February

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Month	Monitoring Targets	Husbandry Options
February	Roots reaching 0.8 m, and plants with 7th MS leaf & >4 shoots. GAI=0.8 (30% ground-cover)	Apply ~30 kg/ha P_2O_5 (& 12 kg/ha N) as DAP (this could be better in the autumn, if N use in autumn was not prohibited)
March	Roots reaching 1.0 m, and plants with 8-9 mainstem leaves & >4 shoots. GAI=1.5 (50% ground-cover)	Apply PGR Apply AN as normal Leaf sample for multi-nutrient analysis, and foliar sprays accordingly Strobilurin at T0
April	Roots reaching 1.2 m, MS leaf 10-11 appearing & still >4 shoots. GAI=3-5 (80% green-cover)	Apply PGR Apply main AN with 130 kg/ha MOP (80 kg/ha K_2O) Apply magnesium whatever Leaf sample for multi-nutrient analysis, and foliar sprays accordingly
May	Roots reaching 1.5 m, leaf leaves and then ears appearing & still >600 shoots/m^2, each with 4-5 green stem leaves. GAI=~6 (90% green-cover); good stem sugar (Brix) readings.	Apply PGR Apply AN Spray Phosphorus (according to Brix reading?) Sprays Magnesium (irrespective of analysis) Leaf sample for multi-nutrient analysis, and foliar sprays accordingly Apply biostimulants with T2 spray
June	Roots reaching 2 m; ~600 ears / m^2; ~25 spikelets with 2-3 developing grains per spikelet; 4 green stem leaves; GAI=6-7 (including ears) (>95% green-cover);	Apply AN, ideally before rain Leaf sample for multi-nutrient analysis, and foliar sprays accordingly – esp Magnesium Apply T3 as strobilurin or SDHI Biostimulants with T3 spray
July	Senescing from 3 green stem leaves at start through to 31st July when there should still be at least partly green flag leaves and leaf sheaths (still giving 25-50% green interception).	Apply AN, ideally before rain
August	A bit of residual green area at the start; ~600 ears / m^2; each with >55 grains, hence >32,000 grains/m^2 each of >50mg @ 15% moisture … hence ~16 t/ha grain	[Harvest]

Results

Of the 11 trials set up in Autumn 2018, yield data were obtained from 8 trials, with extra superimposed treatments at one site giving extra treatment combinations. All sites had adequate levels of major soil nutrients (Table 2) but levels of nutrients in leaf samples measured at GS30 & GS31 showed a few deficiencies at some sites (Table 3), particularly of magnesium (Mg) and boron (B), but of potassium (K) in one case (Site 4). Products used in the Crop Momentum treatments did not necessarily contain these (or any) inorganic nutrients, and leaf samples were not replicated so their representativeness can only be judged by whether differences from the Farm Standard treatment were repeated at all sampling occasions. Nutrients showing consistent differences are shown in Table 3. Note that no significant responses of cereals to boron applications have been recorded previously, according to the review by Roques *et al*. (2013), so the common observation of B deficiency here may be an artefact of a spuriously high threshold.

Table 2. Soil Nutrients, texture and health measured in spring 2019.

Site	pH water	Available Phosphorus (mg/l)	Available Potassium (mg/l)	Available Magnesium (mg/l)	Organic Matter LOI (% w/w)	CO2 Soil Respiration (mg/kg)	Textural Classification	Soil Health Index
1	7.3	12	110	50	2.5	23	Sandy Clay Loam	2.3
2	6.1	32	175	115	8.6	166	Clay Loam	5.7
3	6.7	19	232	425	5.2	148	Clay Loam	5.1
4	7.4	10	122	60	8.7	159	Clay Loam	5.2
5	5.8	37	189	126	6.3	148	Sandy Loam	5.3
6	6.4	71	408	68	5.6	287	Clay Loam	5.7
7	-	-	-	-	-	-	-	-
8	7.6	32	143	33	3.1	127	Sandy Loam	4.2

Table 3. Leaf nutrient status measured in spring 2019. Deficient if N<2.2%, K<2.5%, S<0.28%, P<0.23%, Ca<0.16%, Mg<0.1%, Mn<20ppm, Zn<20ppm, Fe<10ppm, B<4ppm, Cu<3ppm, Mo<0.2ppm.

Site	*Nutrient deficiencies noted in the Farm Standard treatment, if occurring at both GS30 & GS31*	*Consistent differences of Momentum from Farm Standard, % of Farm Standard value, averaged from GS30-59*
1	Mg	B -11%; Mo +10%
2	B	Cu +22%
3	Mg, Zn, B	B -11%; Mo +10%
4	K	NA
5	B	K -4%; Cu -16%
6	None	P +16%; Mn +64%; Mo -30%
7	B	B +34%; Cu +35%; Zn +13%
8	Mg, B	None

Treatments applied are shown in Table 4, along with modelled yield differences for sites taken to completion. Yield differences are between the Momentum treatment and the Farm Standard.

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Table 4. 2019 yield results for sites taken to completion. Modelled yield difference for the Momentum treatment compared to the Farm Standard.

Site	Treatments	Farm standard average yield[ǂ] (t/ha)	Modelled yield difference from farm standard t/ha		SED	LSD
1	Advance	10.40		-0.01	0.133	0.26
2	T0: Biotrac, Gramitrel and Bortrac; T1: Biotrac and Kurus; T2: Orthophos, Bortrac and Gramitrel	11.70		-0.04	0.233	0.46
3	Agrovista CCC / Barleyquat / Bettaquat, Si-NRG, Amino Z, SI-NRG, optE-Phos	9.94		-0.30	0.295	0.59
4	Manganese, Foliar potash, Zintrac, Liquigro	9.53		+0.15	0.310	0.61
5	Gramitrel 2l @ T0, T1, T2 (N, Mg, Mn, Cu & Zn replacing 'Smart Mn').	13.60		+0.62***	0.220	0.43
6	Bridgeway (amino acid based biostimulant)	10.20		+0.93	*#1*	*#1*
7	Multiple treatments #3	13.02		-0.23	0.222	0.44
8A	Bridgeway (biostimulant), autumn, T1 & T2	13.81		-0.15	0.128	0.25
8B	Bridgeway (BW) or/& Calibra Carbo (biostimulant; CC) *#4*	13.56	BW only	+0.84***	0.222	0.41
			CC only	+0.26	0.210	0.44
			BW+CC	+0.93***	0.205	0.40

***Significant with >99% confidence

#1 Treatments located in adjacent fields, no viable comparison

#2 Treatment areas too small and not aligned with field variation, no viable comparison

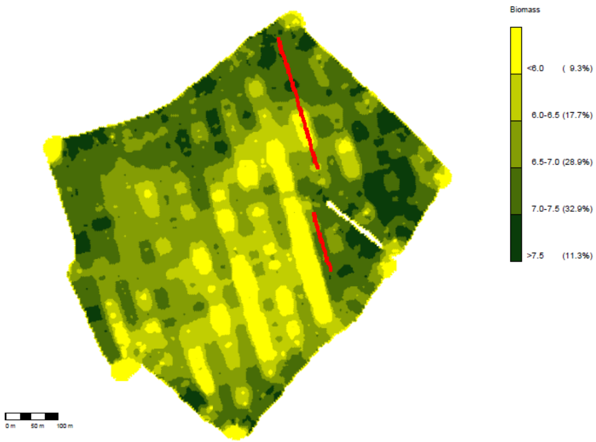
#3 Crop Rooter Plus (ILEX; N, P, K, phosphite & amino acids), MnCu (ILEX), Di-ammonium phosphate, Bridgeway (amino acid biostimulant), EPSO Top (Mg sulphate), Comet (strobolurin), MnCu (ILEX), PK Max (ILEX), EPSO top, Bridgeway, Gamitrel (N, Mg, Mn, Cu & Zn), PK Max (ILEX; phosphite with N, P, K, Mg, S & trace elements.), Foliar Boost (ILEX; Mn (12%) with N, S, Mg, Cu & Zn), Bridgeway, Boron, Efficient N28, 4L MgPlus (ILEX; Mg & N), Bridgeway, Efficient N28.

#4 Farm Standard was compared with Bridgeway (applied in autumn, & at T1 & T2), with Calibra Carbo (applied just at T2), and with both, in these biostimulants combination.

The 2018-19 season was relatively stress-free in terms of drought stress or periods of low radiation inhibiting plant assimilation. However, farmers clearly anticipated deficiencies in nutrient supplies and attempted to correct these with a range of treatments (Table 3).

Significant yield responses were only seen at Sites 5 and 8B (where there were superimposed treatments). Both sites were high yielding and on light textured soils. Both Site 5 and Site 8 (Fig. 1) showed variation in NDVI (ground cover) in early spring (maybe due to treatments applied in autumn). Variable rate nitrogen was applied at Site 8 which, although leading to savings in fertiliser costs, may have moderated any responses to autumn treatments. Treatments with Bridgeway at Site 8B did however show responses which could be attributed to the same treatments as 8a (i.e. there was no significant response to calibri carbo). Site 8a was located in an area of the field exhibiting a higher early spring biomass and, as N applications were similar for all treatments, this might help to explain the apparent differences in response.

Figure 1: Biomass (derived from NDVI measurements) at Site 8 on 25/03/19; low NDVI (yellow strips) correspond to farm standard treatments.



Discussion & Conclusions

The idea of establishing crop momentum implies that crop monitoring and then corrective treatments should begin at or very soon after sowing. However, momentum treatments here were all decided well after crop establishment, so the farmers did not follow the early stages of the Momentum Menu (Table 1). Also, given that the season (of 2019 harvest) lacked significant drought stress, the notion that repeated treatments might over-come stresses was not properly tested. On the other hand, the observation in YEN crops that high yields have generally associated with frequent applications was tested by most of the farms, albeit that the treatments chosen comprised biostimulants and micro-nutrients rather than macro-nutrients, fungicides and PGRs.

Through being part of the YEN leaf samples, leaf analysis was undertaken for all crops. However, when choosing their treatments, growers did not respond directly to these results, i.e. few treatments were chosen in response to specific observations (e.g. low tissue magnesium at Sites 1, 3 & 8 did not prompt magnesium sprays at any of those sites!); rather, it appears that treatments were often chosen 'just in the hopes' that they would elicit responses, irrespective of observed nutrient deficiencies. In fact growers observed that time was often insufficient to sample the crop, obtain the nutrient analysis from the lab and then obtain and apply an appropriate product in time to elicit the desired crop response. They thus tended to choose products which they already had in stock, or which they were being offered by their suppliers.

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The general lack of response to treatments may be interpreted either as crops already having adequate resources and growth, or as the treatments being impotent (in terms of effecting uptake). In either case, it is clear that these farms' current interpretation and attempts to enhance Crop Momentum were largely ineffective. Yields with farm standard husbandry at Sites 2, 5, 7 & 8 were all above the YEN average, and several exceeded 13 t/ha, so it is to be expected that 'stresses', if they occurred, must have been smaller and more difficult to diagnose than in an average crop.

The two sites that did see significant positive effects both had high yields, sandy soils, and adopted a relatively simple approach in terms of product number and type. The response at Site 5 to Gramitrel implies that at least one nutrient out of nitrogen, magnesium, copper and zinc was inadequate compared to the Farm Standard (which only received straight manganese). However, leaf analysis showed all these nutrients to be at adequate levels (Table 3), and treatment was associated with a decrease rather than an increase in leaf copper content!

The response to Broadway at Site 8 is also difficult to explain on the basis of crop health and nutrient contents. Although Mg & B were at low levels in leaf tissue, treatment did not increase either of these nutrients. It should also be noted that the Amino Acid FIG within the YEN Yield Testing Project found no positive (or negative) responses to Bridgeway applications out of the ten tests they made.

Overall these trials were inconclusive, because they were restricted to only one growing season, and because growers only adopted the Crop Momentum idea in part. Whether or not treatments seek to maintain Crop Momentum, it seems that greater care is needed to support decision-making on additional products such as those tested here. Indeed, in some cases, there appeared to be little basis for the choices being made. That all crops should respond to biostimulants and multi-nutrient sprays seems improbable, so it should prove worthwhile to base their use and timing at least on (i) the status and needs of the crop, and (ii) independent evidence for efficacy of the products themselves. With this in mind, ADAS is planning to launch a new service called 'YEN Nutrition' which facilitates diagnosis of crop nutrient requirements. Also, it is fortunate that EU Fertiliser Regulations are shortly due to be enacted to require the provision of information on efficacy of nutritional products and biostimulants for crops.

<u>Reference</u>

Roques, S., Kendall, S., Smith, K., Newell Price, P. & Berry, P. (2013). *A review of the non-NPKS nutrient requirements of UK cereals and oilseed rape*. AHDB Research Review No. 78. Pp. 108.