STAR Project

Sustainability Trial in Arable Rotations

Year 15 - 2019/20

A report for The Felix Thornley Cobbold Agricultural Trust and The Morley Agricultural Foundation

Winter 2020

This project was delivered through NIAB TAG in accordance with the agreed protocol and associated Standard Operating Procedures. The results presented fully and accurately reflect our interpretation of the data generated.

Signed:

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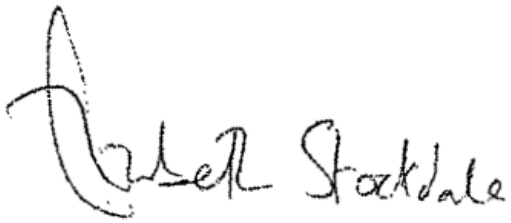
Date: 09/12/2020



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Results and conclusions for the 15th year of the STAR Project (2019-20) are contained in this document. This report is based on feedback, guidance and interpretation delivered by the STAR Project steering group.

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1. SUMMARY

The STAR Project (Sustainability Trial in Arable Rotations) is a long-term study at Stanaway Farm, Otley, Suffolk on a Beccles/Hanslope Series clay soil. Research delivered through NIAB TAG, supported by The Felix Thornley Cobbold Trust, The Morley Agricultural Foundation and historically, the Chadacre Agricultural Trust and guided by an independent steering group, is examining the interaction of four rotations and four cultivation techniques. During Year 15 (2019/20) the entire experiment, apart from the herbal ley, was in spring -sown wheat (cv Belepi) sown in April 2020 due to the wet autumn/winter. Cultivation techniques are described as annual ploughing, deep tillage (non-inversion to 20 cm), shallow tillage (non-inversion to 10 cm) and a managed approach (where cultivation decisions are based on best practice guided by field conditions at the time of cultivation and past soil assessments).

In Year 15, the highest crop yields were generally associated with shallow tillage within the spring and continuous wheat cropping. The impact of growing sugar beet in the previous season appeared not to have had a detrimental impact on wheat yield, although this was likely to have been mitigated by lifting the sugar beet early in the campaign.

Soil penetration resistance indicated that shallow tillage approaches are continuing to exhibit increasing soil strength compared to the plough and deep tillage approaches in the 10-35 cm soil profile. In addition to the shallow tillage exhibiting greater soil strength, the managed approach also indicated greater soil strength. This may partly be due to the winter cropping and continuous wheat rotations both using shallow tillage in the two previous seasons (2019 and 2020) based on other management considerations such as managing the weed seed bank and retaining soil moisture in autumn 2019 (when WOSR was sown in the winter cropping rotation). This highlights the requirement for greater soil disturbance on a rotational basis to alleviate an increase in soil strength that may restrict crop rooting.

Margins (calculated as gross output minus input costs and direct machinery costs) were highest in the shallow tillage approach. The farming system platforms created through the STAR Project are being seen increasingly as valuable research and knowledge transfer tools in their own right.

Long-term findings demonstrate clear impacts of rotation and cultivation on agronomy and production, including (but not limited to) weed burden, soil condition and mycotoxin risks. With regard to yields and margins, differences between cultivation systems have been relatively small, however, the highest yields and margins, considered over all crops, have been associated with the managed approach and underlines the need for a flexible approach.

Further long-term trends from the STAR Project (Years 1-10) can be read in the long-term report available at www.niab.com.

2. AIM & OBJECTIVES

AIM

- To examine different cultivation systems for sustainable arable production.

OBJECTIVES

- To examine different rotation systems and to explore how they interact with cultivation systems and required inputs.
- To demonstrate to Suffolk farmers on Beccles/ Hanslope series clay loam soil alternative systems of cultivation across the rotation.

3. ACKNOWLEDGEMENTS

The STAR Project is delivered through NIAB TAG, supported in part by The Felix Thornley Cobbold Trust, The Morley Agricultural Foundation and historically by the Chadacre Agricultural Trust.

In recent seasons some support has also been delivered through external projects making use of the platform and a number of PhD research projects. The research has also benefitted from an independent steering committee. This includes local farmers and consultants; thanks and acknowledgement are extended to John Taylor (our host farmer) and other members of this group.

Table 1: Summary of STAR Project rotation and cultivation treatments

Rot	2006 (Yr 1)	2007 (Yr 2)	2008 (Yr 3)	2009 (Yr 4)	2010 (Yr 5)	2011 (Yr 6)	2012 (Yr 7)	2013 (Yr 8)	2014 (Yr 9)	2015 (Yr 10)	2016 (Yr 11)	2017 (Yr 12)	2018 (Yr 13)	2019 (Yr 14)	2020 (Yr 15)
1	wosr	ww	wbn	ww	wosr	ww	wbn	ww	wosr	ww	wbn	ww	ww	wosr	sw
2	sbn	ww	soats	ww	sbn	ww	Sln	ww	soats	ww	sbn	ww	ww	sbeet	sw
3	ww	ww	ww	ww	ww	ww	ww	ww	ww	ww	ww	ww	ww	ww	sw
4	fal+scc	ww	fal+scc	ww	fal+scc	ww	fal+scc	ww	fal+scc	ww	fal+slcc	ww	ww	herbal ley	herbal ley

Rotation key – 1 winter cropping, 2 spring cropping 3 continuous wheat, 4 Alt fallow + cc / herbal ley
Cropping key – ww (winter wheat), sw (spring wheat), wosr (winter oilseed rape), soats (spring oats), sbn (spring bean), wbn (winter bean), sln (spring linseed), fal+scc (fallow with spring cover crop), fal+slcc (fallow with season-long cover crop), herbal ley (3 year herbal ley)

	Cultivation	
1	Annual plough	Treatment is ploughed every year.
2	Managed approach	Decision on cultivation regime varies with season and is based around soil/weather conditions, previous cropping, weed burden, soil assessments etc.
3	Shallow tillage	Treatment is cultivated to »10 cm using a non-inversion technique.
4	Deep tillage	Treatment is cultivated to »20-25 cm using a non-inversion technique.

4. BACKGROUND

In autumn 2005 a field experiment was set up at Stanaway Farm, Otley (Suffolk), funded by the Felix Thornley Cobbold Trust, to study different cultivation techniques within a series of arable rotations; this research project was termed the STAR Project (Sustainability Trial in Arable Rotations). The experiment was established in Nelson Field as a fully replicated, large plot (36 m x 36 m), trial on a Beccles/Hanslope soil (which is representative of many farms in the region). The large plot system ensures that modern techniques and farm scale equipment can be utilised to reflect local farm practice, unlike many previous experiments. Four cultivation techniques and four rotations are employed, resulting in 16 treatments. These treatments are outlined in Table 1 (previous page).

Data interpretation and key grower messages from this project come from both direct information (e.g. impacts on soil parameters, grass weed populations, crop disease levels, grain/seed yields and grain mycotoxin levels) and from derived financial analysis (e.g. gross margins minus machinery costs for each scenario). These results help farmers to make informed strategic decisions in relation to their businesses. Further, over recent seasons, a parallel research project being undertaken through NIAB TAG at Morley in Norfolk (The New Farming Systems (NFS) study

Table 2: Summary of trial information

Trial Id	**WW20-002**	
Location	Nelson Field, Stanaway Farm, Otley, Ipswich, Suffolk	
Cropping	*Rotation description* Winter cropping: Spring cropping: Continuous wheat: Alternate fallow / herbal ley:	*Cropping in 2019/20* Spring-sown wheat: *cv.* Belepi Spring-sown wheat: *cv.* Belepi Spring-sown wheat: *cv.* Belepi Herbal Ley (3-year)
Cultivations	*Description* *Annual plough* – Ploughed *Managed approach* – where cultivation decisions are based on best practice *Shallow non-inversion* – Sumo Trio - working with discs and legs raised (10 cm) *Deep non-inversion* – Sumo Trio - working with discs and deeper legs (20 cm) *Full details of cultivation methods are shown in Appendix A.*	
Drilling date	*Cropping in 2020* Spring-sown wheat: Herbal Ley (3-year):	 05/04/20
Seed rate	*Cropping in 2020* Herbal Ley:	 200kg/ha (500 seeds/m^2)
Inputs & husbandry	Appropriate to treatment and best practice.	
Harvest date	*Cropping in 2020* Spring-sown wheat: Herbal Ley (3-year):	 21/08/20 -
Trial design	Factorial	
No. of replicates	3	
Plot size	36 m x 36 m approx. (drilled with commercial farm equipment)	
Analysis	ANOVA with LSD quoted at P = 0.05	

funded by TMAF and the JC Mann Trust) containing analogous long-term replicated cultivation research (with similar measurements and financial assessments) has helped to extend and develop the interpretation and ensure that findings can be applied across a wider range of soil types.

5. METHODS

Detailed trial information and outline methods are set out in Table 2. In 2019/20 the study was in wheat other than the herbal ley.

6. RESULTS & DISCUSSION

Results contained in this report are ostensibly from a single season (Year 15, 2019/20) of a long term project and should therefore be treated with some caution and considered in context with previous STAR reports.

The weather through autumn and winter 2019/20 was particularly challenging for many growers. Whilst conditions during early September allowed for primary cultivations to be completed ready to sow winter wheat in October 2019, the significant rainfall through the autumn and winter made this impossible to achieve. Met Office anomaly rainfall maps (Figure 1) for the autumn 2020 rainfall was around 150% of the 1981 – 2010 average. By spring the conditions turned from very

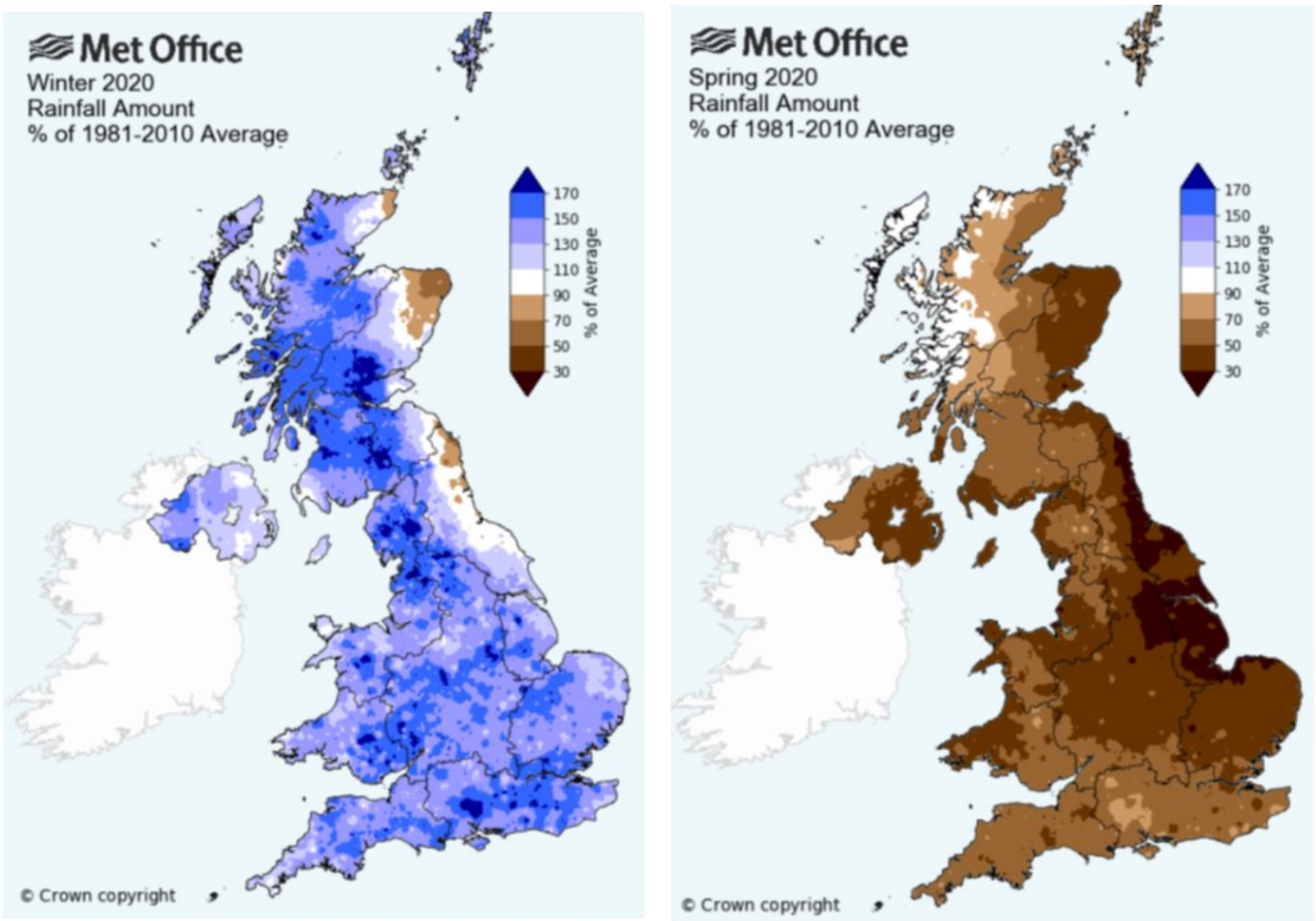

Figure 1: MET Office anomaly maps for rainfall during winter and spring 2020.

wet to very dry with the spring 2020 rainfall only 30% of the 1981-2010 average.

In the 2019/20 season, STAR Project Year 15, the study was in a first wheat (see Table 2) and sown with spring-sown wheat (cv. Belepi, sown 05/04/20). The wheat plant populations were similar for winter, spring and continuous wheat cropping (Table 3) with, on average 179, 194 and 175 plants/m^2 respectively. Although not significantly different, the spring rotation (after sugar beet) resulted in slightly higher plant populations than the other two rotations and this is believed to partly be as a result of improved seedbed tilth following the sugar beet.

Due to the particularly dry spring, whilst the wheat established reasonably well, the dry April and May limited the crop's ability to tiller resulting in low numbers of fertile tillers (Table 3). Fertile tillers in the winter and spring rotations averaged 244 and 259 tillers/m^2 respectively. Whilst in the continuous wheat, the plough, deep and shallow tillage treatments resulted in 214-220 fertile tillers /m^2.

Soil penetration resistance (PR) was collected in March 2020 (Figure 2). This indicated that shallow tillage approaches are continuing to exhibit increasing soil strength compared to the plough and deep tillage approaches in the 10-35 cm soil profile. In addition to the shallow tillage exhibiting greater soil strength, the managed approach also indicated greater soil strength. This may partly be due to the winter cropping and continuous wheat rotations, both using shallow tillage in the two previous seasons (2019 and 2020), based on other management considerations such as managing the weed seed bank and retaining soil moisture in autumn 2019 (when WOSR was sown in the winter cropping rotation).

Typically, the managed approach receives greater soil disturbance (deep non-inversion or ploughing) on a rotational basis, last carried out in 2018. The alternate fallow/herbal ley plots were sown on 03/09/18 with a herbal ley consisting of 14 species of both legumes, grasses and forb (herbaceous flowering plants) species with a range of rooting depths, some being deep rooted with the aim to aid soil fertility and structure. This ley will remain for three years before being returned to arable production in autumn 2021. In-season management will involve mowing when required with the material baled and wrapped for silage.

Yield and margin data from the 2019-20 season are presented in Table 4 with a breakdown of costs presented in Appendix B. In the winter and spring cropping rotations the wheat yielded similarly across all cultivation approaches with a

Table 3: Plant population and canopy cover from STAR Year 15 (2019/20)

	Plant populations (assessed 29/04/20)					Ears/m^2 (assessed 07/07/20)			
Tillage	Winter (/m^2)	Spring ('000s/ha)	Cont (/m^2)	Herbal ley		Winter	Spring	Cont	Herbal ley
Plough	175	188	174	-		241	275	220	-
Managed	179	202	171	-		242	275	279	-
Shallow	187	197	172	-		250	245	214	-
Deep	173	190	183	-		242	239	216	-
Average	179	194	175	-		244	259	232	-
LSD (5%)			27.7					33.4	
CV %			9.0					8.2	

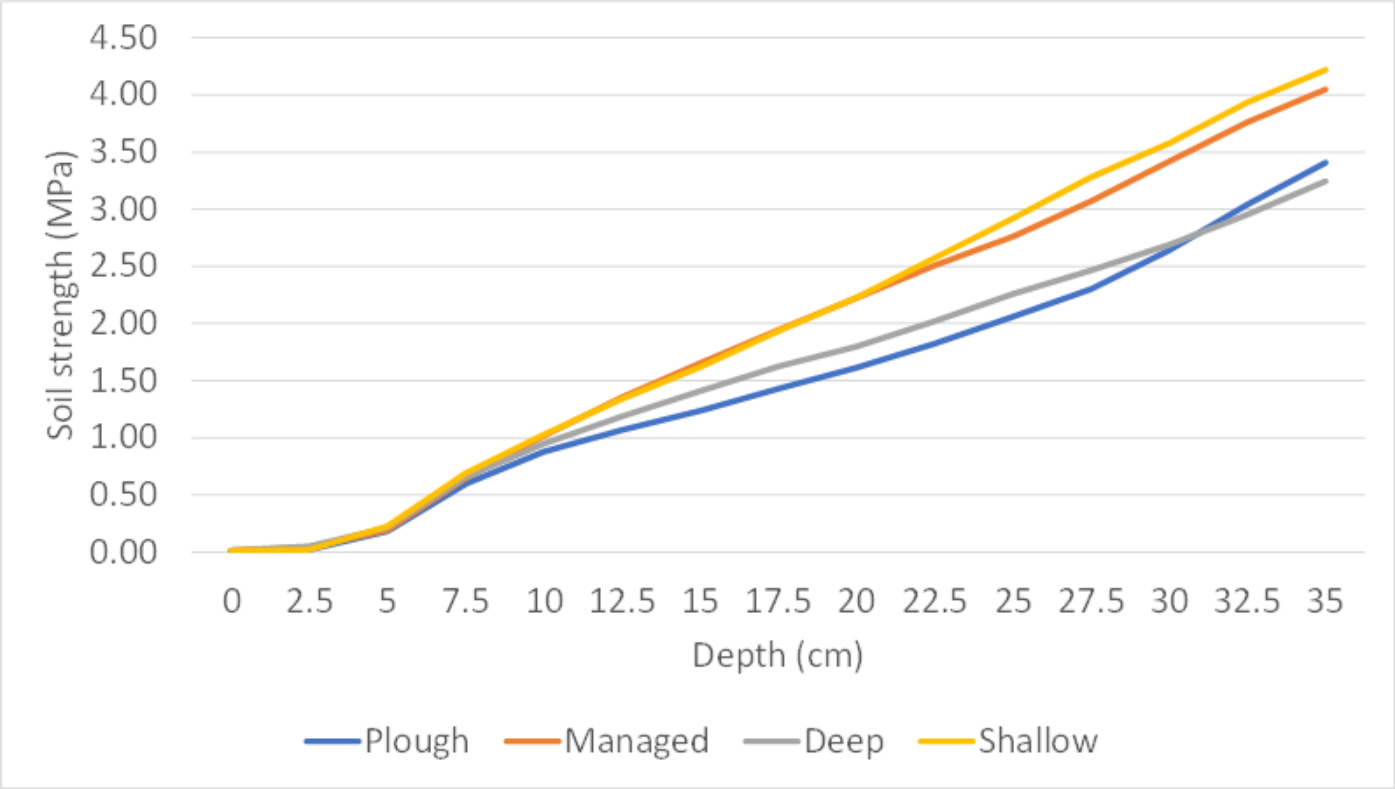

Figure 2.: The effect of cultivation, irrespective of rotation, on soil penetration resistance.

Table 4: Yield and margin summary information from break crops in STAR Year 15 (2019/20)

	Yield (t/ha)					Gross margin – machinery cost (£/ha)			
	Winter	Spring	Cont	Alt Fallow		Winter	Spring	Cont	Alt Fallow
Plough	6.69	6.31	5.76	-		643	577	480	-
Managed	6.49	6.29	5.71	-		676	573	540	-
Shallow	6.38	6.61	5.94	-		657	697	580	-
Deep	6.65	6.12	5.26	-		692	599	449	-
Average	6.55	6.33	5.67	-		667	612	512	-
LSD			0.61	-					
CV %			5.8	-					

Margins represent a gross output minus direct input and machinery costs. Margins use diesel at £0.56/l; N at £0.67/kg N; wheat at £175/t.

mean yield of 6.55 t/ha and 6.33 t/ha, respectively. Yields were highly significantly lower in the continuous wheat rotation (P=<0.001), with a mean yield of 5.67 t/ha.

Summary financial analysis from the 2019-20 seasons are presented in Table 4. Excluding the impact of cultivation, on average, highest margins tended to be associated with the winter cropping (£667/ha) and the lowest with continuous wheat (£512/ha). Excluding the effect of rotation, the highest margin was from the shallow tillage approach (£645/ha). In general, the higher average yields associated with specific establishment systems followed through into higher average margins.

Grain quality (specific weight and grain protein) is shown in Table 5. Across all rotations, irrespective of tillage, specific weight on average was 75.1, 74.6 and 75.3 kg/hl in the winter, spring and continuous wheat rotations respectively with no significant differences. Grain proteins were, on average, between 12.9% and 13.0% in the winter and spring rotational approaches, resulting in no significant differences. However, there were significant differences in the continuous wheat rotation between tillage approaches. The highest grain protein was in the plough tillage (13.5%) and this was significantly higher (P=<0.01) compared to the shallow tillage approach (12.5%). On average the grain protein met target specifications and commanded a premium in grain price over feed wheat.

Table 5: Grain quality (cv. Belepi; Group 4) in STAR Year 15 (2019/20)

	Specific weight (kg/hl)					**Grain protein (%)**			
	Winter	Spring	Cont	Alt Fallow		Winter	Spring	Cont	Alt Fallow
Plough	74.7	74.5	75.8	-		12.9	13.0	13.5	-
Managed	75.3	74.9	75.5	-		12.8	13.5	12.6	-
Shallow	74.9	74.7	74.4	-		12.8	12.9	12.5	-
Deep	75.5	74.3	75.5	-		13.2	13.1	13.1	-
Average	75.1	74.6	75.3	-		12.9	13.0	12.9	-
LSD			1.29	-					
CV %			1.0	-					

7. CONCLUSIONS

As with previous seasons the STAR Project continues to develop and produce strategic information for a wide range of audiences including growers, agronomists and commercial organisations. The challenging weather in the autumn and winter of 2019/20, as with many growers, resulted in a delay to spring drilling. Met Office anomaly rainfall maps for the winter 2020 rainfall was around 150% of the 1981–2010 average with ground conditions not ready to travel on until spring 2020. The wet winter then turned into one of the driest springs on record and resulted in a lower tillering capacity of the crop. However, given the challenging season, yields were respectable averaging between 5.67 t/ha and 6.55 t/ha, with the lowest yields seen in the continuous wheat rotation.

Margin reflected yield with the highest yield and margin obtained with shallow tillage. The impact of growing sugar beet in the previous season showed little impact on crop performance in the wheat. Quantification of system impacts on soils within the STAR Project will continue over coming seasons (to assess long-term changes) and will also continue to be carried out in the analogous treatments in the NIAB TAG New Farming Systems study at Morley. Interpreting these measurements in the context of these replicated experiments helps to generate a wider generic understanding of these impacts across a range of soil types.

The STAR Project provides an excellent opportunity to demonstrate farming systems to local farms in East Anglia and continues to help farmers, both locally and nationally, to make informed decisions on the possible impacts that rotations and cultivations can have on their businesses. The site also acts as a platform to help facilitate wider research into changes in farming systems and ecosystem services that are becoming of increasing focus under social and political change. It also continues to provide a valuable resource for supporting PhD students to collect samples from as part of their research study.

8. KNOWLEDGE TRANSFER

The STAR Project continues to attract a high level of interest both regionally and nationally. The Project has been presented at a range of conferences and training events run through NIAB TAG as well as events run by other organisations. The Project has also received exceptionally good media coverage including articles in conference proceedings and a range of farming press articles.

Due to Covid-19 restrictions the field day was cancelled in 2020 but we hope to return as soon as we can. Proactive and effective knowledge transfer, both locally and to the whole industry, remains an integral part of NIAB TAG's delivery of the STAR Project; this ensures that messages reach the widest possible audience. A list of all KT activities is captured in the Steering Group meeting minutes, with a few key events and publications highlighted below:

- CropTech Event Online Hub 'Quantifying and alleviating subsoil compaction in arable soils' – November 2020
- Used in NIAB TAG training courses on rotations, Professional Development Training for Farmers, with various farmer groups (e.g. NFU regional group) and other parties (e.g. consultant groups, Colleges and Universities)
- NIAB CTF Network article on deep compaction – June 2020
- NIAB TAG Membership report on 'Confirming and characterising resistance levels in Meadow and Rye Brome samples' – June 2020

APPENDIX A: CULTIVATION APPROACH SUMMARY

Appendix Table 1: Cultivations and equipment used to establish each treatment

	Winter cropping	**Spring cropping**	**Alternate fallow**	**Continuous wheat**
Plough	Plough (20 cm) Power Harrow (x2) Vaderstad Cultivator Drill Roll	Plough (20 cm) Power Harrow (x2) Vaderstad Cultivator Drill Roll	-	Plough (20 cm) Power Harrow (x2) Vaderstad Cultivator Drill Roll
Man-aged	Sumo (10 cm) Power Harrow (x1) Vaderstad Cultivator Drill Roll	Plough (20 cm) Power Harrow (x2) Vaderstad Cultivator Drill Roll	-	Plough (20 cm) Power Harrow (x2) Vaderstad Cultivator Drill Roll
Shallow	Sumo (10 cm) Power Harrow (x1) Vaderstad Cultivator Drill Roll	Sumo (10 cm) Power Harrow (x1) Vaderstad Cultivator Drill Roll	-	Sumo (10 cm) Power Harrow (x1) Vaderstad Cultivator Drill Roll
Deep	Sumo (20 cm) Power Harrow (x1) Vaderstad Cultivator Drill Roll	Sumo (20 cm) Power Harrow (x1) Vaderstad Cultivator Drill Roll	-	Sumo (20 cm) Power Harrow (x1) Vaderstad Cultivator Drill Roll

APPENDIX B: COST AND MARGIN BREAKDOWN

Appendix Table 2a: STAR cost and margin breakdown 2019/20 (winter cropping)

	Shallow Till	Deep Till	Managed App	Annual Plough
	Spring wheat			
Yield (t/ha)	**6.38**	**6.65**	**6.49**	**6.69**
Price (£/t)	**175**	**175**	**175**	**175**
OUTPUT (£/ha)	**1,116.50**	**1,163.75**	**1,135.75**	**1,170.75**
VARIABLE COSTS:				
Seed	90.00	90.00	90.00	90.00
Fertiliser	158.70	158.70	158.70	158.70
Sprays	67.73	67.73	67.73	67.71
Other				
VARIABLE COSTS (£/ha)	**316.43**	**316.43**	**316.43**	**316.41**
GROSS MARGIN - (£/ha)	**800.07**	**847.32**	**819.32**	**854.34**
FIELD OPERATIONAL COSTS (£/ha)				
Plough				60.00
Deep Sumo		41.00		
Shallow Sumo	29.00		29.00	
Power Harrow (x1 or x2)	37.00	37.00	37.00	74.00
Double press				
Single Pass Drill				
Combi Drill				
Tine Drill				
Claydon Drill				
Cultivator Drill	28.00	28.00	28.00	28.00
Rolls	13.00	13.00	13.00	13.00
Quad				
Fertiliser (x2)	12.00	12.00	12.00	12.00
Sprayer (x6)	24.12	24.12	24.12	24.12
Total Field Operational Costs (£/ha)	**143.12**	**155.12**	**143.12**	**211.12**
MARGIN MINUS COSTS (£/ha)	**656.95**	**692.20**	**676.20**	**643.22**

Appendix Table 2b: STAR cost and margin breakdown 2019/20 (spring cropping)

	Shallow Till	Deep Till	Managed App	Annual Plough
	Spring wheat			
Yield (t/ha)	**6.61**	**6.12**	**6.29**	**6.31**
Price (£/t)	**175**	**175**	**175**	**175**
OUTPUT (£/ha)	**1,156.75**	**1,071.00**	**1,100.75**	**1,104.25**
VARIABLE COSTS:				
Seed	90.00	90.00	90.00	90.00
Fertiliser	158.70	158.70	158.70	158.70
Sprays	67.73	67.73	67.73	67.71
Other				
VARIABLE COSTS (£/ha)	**316.43**	**316.43**	**316.43**	**316.41**
GROSS MARGIN - (£/ha)	**840.32**	**754.57**	**784.32**	**787.84**
FIELD OPERATIONAL COSTS (£/ha)				
Plough			60.00	60.00
Deep Sumo		41.00		
Shallow Sumo	29.00			
Power Harrow (x1 or x2)	37.00	37.00	74.00	74.00
Double press				
Single Pass Drill				
Combi Drill				
Tine Drill				
Claydon Drill				
Cultivator Drill	28.00	28.00	28.00	28.00
Rolls	13.00	13.00	13.00	13.00
Quad				
Fertiliser (x2)	12.00	12.00	12.00	12.00
Sprayer (x6)	24.12	24.12	24.12	24.12
Total Field Operational Costs (£/ha)	**143.12**	**155.12**	**211.12**	**211.12**
MARGIN MINUS COSTS (£/ha)	**697.20**	**599.45**	**573.20**	**576.72**

Appendix Table 2c: STAR cost and margin breakdown 2019/20 (continuous wheat)

	Shallow Till	Deep Till	Managed App	Annual Plough
	Spring wheat			
Yield (t/ha)	**5.94**	**5.26**	**5.71**	**5.76**
Price (£/t)	**175**	**175**	**175**	**175**
OUTPUT (£/ha)	**1,039.50**	**920.50**	**999.25**	**1,008.00**
VARIABLE COSTS:				
Seed	90.00	90.00	90.00	90.00
Fertiliser	158.70	158.70	158.70	158.70
Sprays	67.73	67.73	67.73	67.71
Other				
VARIABLE COSTS (£/ha)	**316.43**	**316.43**	**316.43**	**316.41**
GROSS MARGIN - (£/ha)	**723.07**	**604.07**	**682.82**	**691.59**
FIELD OPERATIONAL COSTS (£/ha)				
Plough				60.00
Deep Sumo		41.00		
Shallow Sumo	29.00		29.00	
Power Harrow (x1 or x2)	37.00	37.00	37.00	74.00
Double press				
Single Pass Drill				
Combi Drill				
Tine Drill				
Claydon Drill				
Cultivator Drill	28.00	28.00	28.00	28.00
Rolls	13.00	13.00	13.00	13.00
Quad				
Fertiliser (x2)	12.00	12.00	12.00	12.00
Sprayer (x6)	24.12	24.12	24.12	24.12
Total Field Operational Costs (£/ha)	**143.12**	**155.12**	**143.12**	**211.12**
MARGIN MINUS COSTS (£/ha)	**579.95**	**448.95**	**539.70**	**480.47**