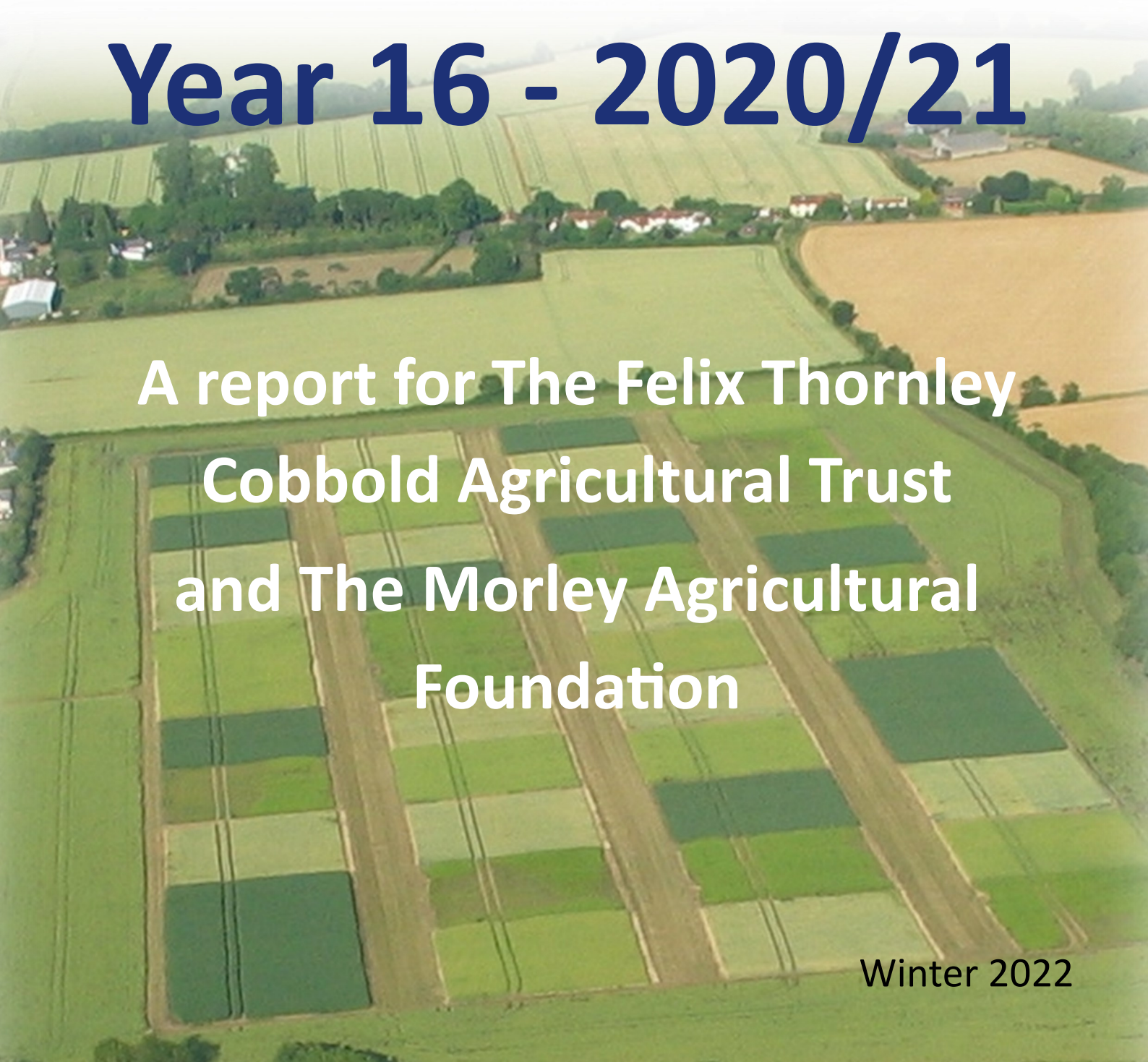
STAR Project

Sustainability Trial in Arable Rotations

Year 16 - 2020/21



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

Winter 2022

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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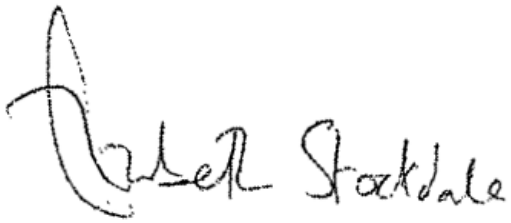
Date: 22/02/2022



Reviewed By:

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Results and conclusions for the 16th year of the STAR Project (2020-21) are contained in this document. This report is based on feedback, guidance and interpretation delivered by the STAR Project steering group.

CONTENTS

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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 16 (2020/21) the study was in a 'break crop year' other than the continuous wheat and herbal ley. The break crops grown were winter beans and spring beans. 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 16, due to the poor autumn conditions, the majority of the winter beans failed (apart from the managed approach) and were redrilled along with the spring beans in the spring. Both the remaining winter beans and all of the spring beans performed poorly yielding between 0.82 and 2.54 t/ha. This was typical of the bean performance on farm and mirrors the dilemma farmers face on Beccles/Hanslope clay soils in achieving reliable, consistent performance from pulses in their rotation. The continuous wheat performed well with a mean yield of 9.02 t/ha and attracting a premium at harvest for attaining >12.0% protein.

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 12.5-35 cm soil profile. In addition to the shallow tillage exhibiting greater soil strength, the managed approach and plough tillage also indicated greater soil strength at depth.

Yield and margin (calculated as gross output minus input costs and direct machinery costs) were highest in the shallow tillage continuous wheat 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.

The monitoring of the three year herbal ley will continue in the coming two seasons, to assess potential for improved performance after returning to an arable rotation in autumn 2021 and monitoring the impact in winter wheat performance (1st and 2nd WW). 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. 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.

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)	2021 (Yr 16)
1	wosr	ww	wbn	ww	wosr	ww	wbn	ww	wosr	ww	wbn	ww	ww	wosr	sw	wb
2	sbn	ww	soats	ww	sbn	ww	Sln	ww	soats	ww	sbn	ww	ww	sbeet	sw	sb
3	ww	ww	ww	ww	ww	ww	ww	ww	ww	ww	ww	ww	ww	ww	sw	ww
4	fal+scc	ww	fal+scc	ww	fal+scc	ww	fal+scc	ww	fal+scc	ww	fal+slcc	ww	ww	herbal ley	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

Table 2: Summary of trial information

Trial Id	**WW21-002**	
Location	Nelson Field, Stanaway Farm, Otley, Ipswich, Suffolk	
Cropping	*Rotation description* Winter cropping: Spring cropping: Continuous wheat: Alternate fallow / herbal ley:	*Cropping in 2020/21* Winter beans: *cv.* Tundra (All apart from 'Managed' re-sown with spring beans) Spring beans: *cv.* Lynx Winter wheat: *cv.* KWS Extase 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 2021* Winter Beans Spring Beans Winter Wheat Herbal Ley (3-year)	 26/11/2020 07/04/2021 06/11/2020 -
Seed rate	*Cropping in 2021* Winter Beans Spring Beans Winter Wheat Herbal Ley:	 400 kg/ha 380 kg/ha 270 kg/ha -
Inputs & husbandry	Appropriate to treatment and best practice.	
Harvest date	*Cropping in 2021* Winter Wheat: *Winter Beans* *Spring Beans* Herbal Ley (3-year):	 11/08/2021 15/09/2021 15/09/2021 -
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	

Norfolk (The New Farming Systems (NFS) study 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 2020/21 the study was in a 'break-crop year' other than the continuous wheat and herbal ley.

6. RESULTS & DISCUSSION

Results contained in this report are ostensibly from a single season (Year 16, 2020/21) of a long term project and should therefore be treated with some caution and considered in context with previous STAR reports.

The weather through the autumn and winter 2020/21 was particularly challenging for many growers. Whilst conditions during early September allowed for primary cultivations to be completed ready to sow winter wheat and winter beans in October 2020, the significant rainfall through the autumn resulted in poor conditions at drilling. Met Office anomaly rainfall maps (Figure 1) for the autumn 2020 rainfall was around 130% of the 1991 – 2020 average. In April 2021 the conditions

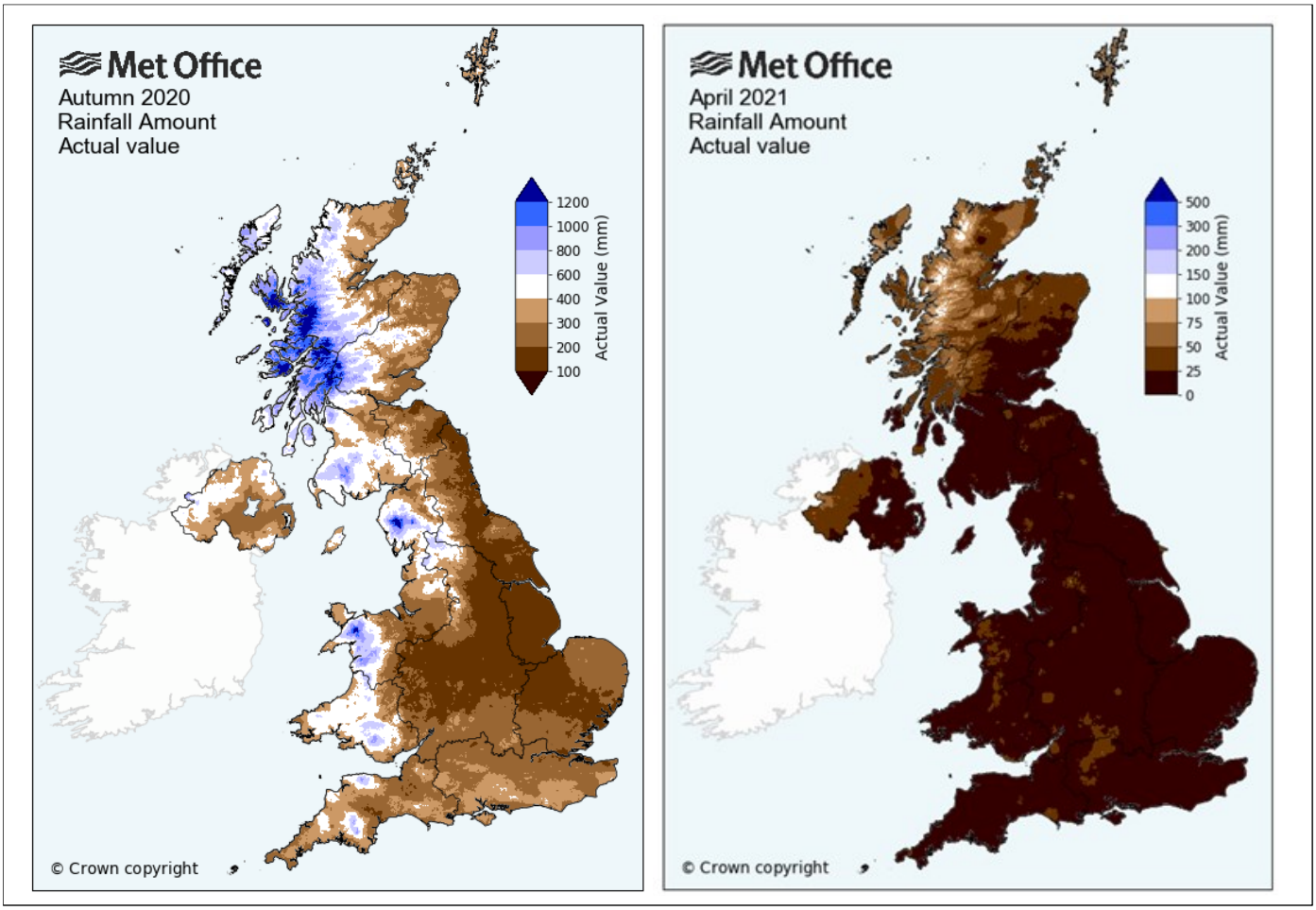

Figure 1: MET Office anomaly maps for rainfall during autumn 2020 and April 2021.

turned from very wet to very dry with the April 2021 rainfall around 0% of the 1991-2020 average.

In the 2020/21 season, STAR Project Year 16, the study was in a 'break crop year' (see Table 2) and sown with winter beans (cv. Tundra, sown 26/11/20, then re-sown with spring beans apart from the 'managed' approach), spring beans (cv. Lynx, sown 07/04/21), and continuous winter wheat (cv. KWS Extase, sown 06/11/20). The failed winter bean plots were caused by poor autumn conditions that did not allow the slot behind the drill to close fully and allowed rooks to pull the seedlings out from the soil. With regards to plant populations, there was no significant difference between any of spring beans, under plough, deep or shallow tillage (Table 3). The only significant difference was with the winter beans 'managed approach', where winter bean seed rates are lower than for spring beans resulting in a lower plant population. The wheat plant populations were not significantly different across tillage (Table 3) with, on average 132 plants/m^2 . On average fertile tillers in the continuous wheat averaged 433 fertile tillers/m^2 . There was no significant difference in fertile tillers between any cultivation approach. All treatments resulted in 3-4 fertile tillers per plant.

Soil penetration resistance (PR) was measured in January 2021 (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 12.5-35 cm soil profile. In addition to the shallow tillage exhibiting greater soil strength, the managed and plough tillage approaches also indicated greater soil strength at depth, compared to deep tillage.

The alternate fallow/herbal ley plots were sown on 03/09/18 with a three year 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. Mowing was carried out once or twice per annum (depending on regrowth) and was baled and removed. The herbal ley was destroyed in June 2021 before being returned to arable production in autumn 2021.

Yield and margin data from the 2020-21 season are presented in Table 4 with a breakdown of costs presented in Appendix B. This season, as

Table 3: Plant population and canopy cover from STAR Year 16 (2020/21)

	Plant populations (assessed 17/05/21)					Ears/m^2 (assessed 07/07/21)			
Tillage	Winter (/m^2)	Spring (/m^2)	Cont (/m^2)	Herbal ley		Winter	Spring	Cont	Herbal ley
Plough	52	54	140	-		-	-	415	-
Managed	(29)	57	121	-		-	-	455	-
Shallow	56	55	131	-		-	-	442	-
Deep	54	54	135	-		-	-	420	-
Average	48	55	132	-		-	-	433	-
LSD (5%)	9.2	11.9	20.5	-		-	-	59.4	-
CV %	9.7	10.8	7.8	-			-	6.9	-

Bracketed figure are winter beans, the rest are spring beans, following re-drilling

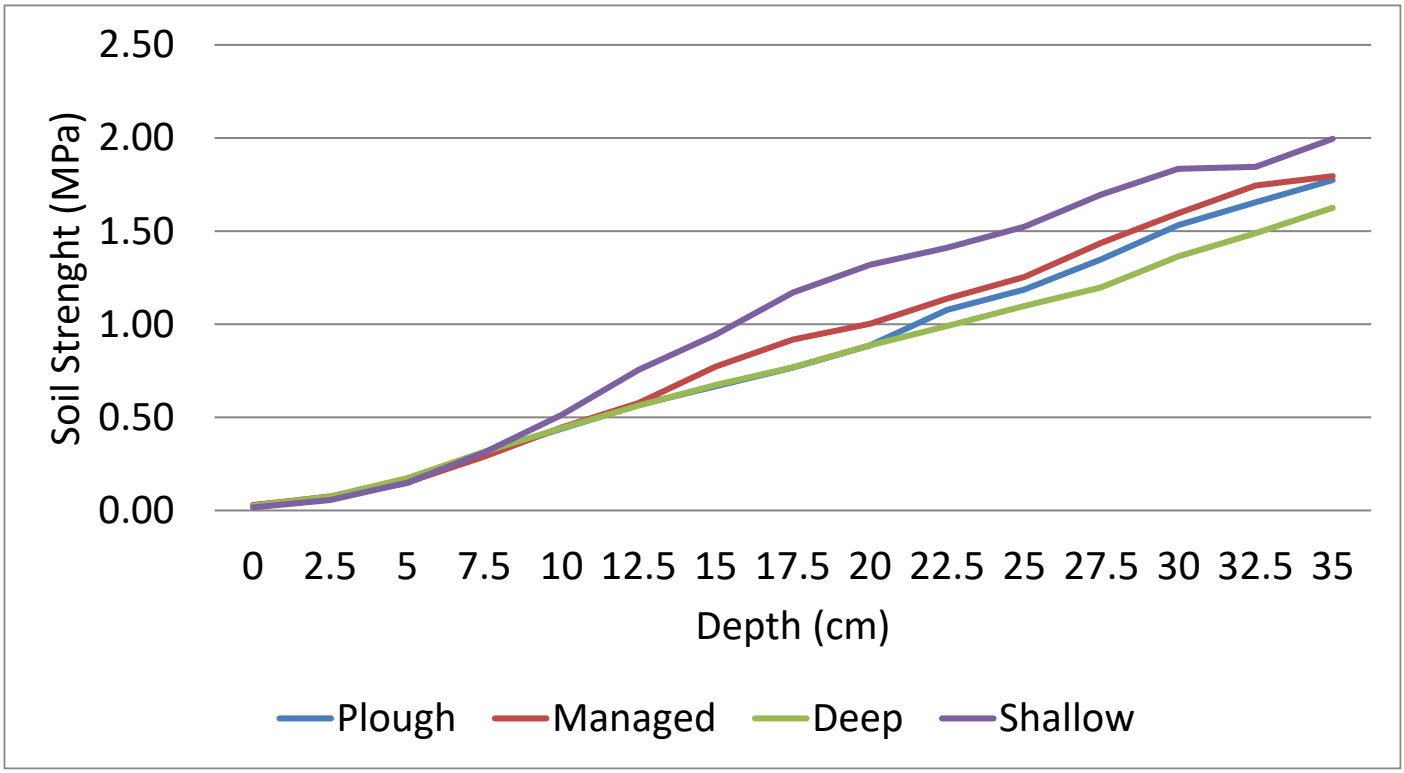

Figure 2.: The effect of cultivation, irrespective of rotation, on soil penetration resistance.

Table 4: Yield and margin summary information from break crops in STAR Year 16 (2020/21)

	Yield (t/ha)					Gross margin – machinery cost (£/ha)			
	Winter	Spring	Cont	Alt Fallow		Winter	Spring	Cont	Alt Fallow
Plough	1.18	2.54	9.14	-		-350	139	1222	-
Managed	(0.82)	2.20	8.67	-		-153	81	1197	-
Shallow	1.19	1.06	9.34	-		-315	-169	1331	-
Deep	1.09	1.76	8.92	-		-350	-20	1235	-
Average	1.07	1.89	9.02	-		-292	8	1246	-
LSD	0.7	1.93	0.8	-		-			
CV %	32.8	51.7	4.7	-		-			

Margins represent a gross output minus direct input and machinery costs. Margins use diesel at £0.58/l; N at £0.68/kg N; wheat at £185/t and beans at £220/t.

Bracketed figure are winter beans, the rest are spring beans, following re-drilling

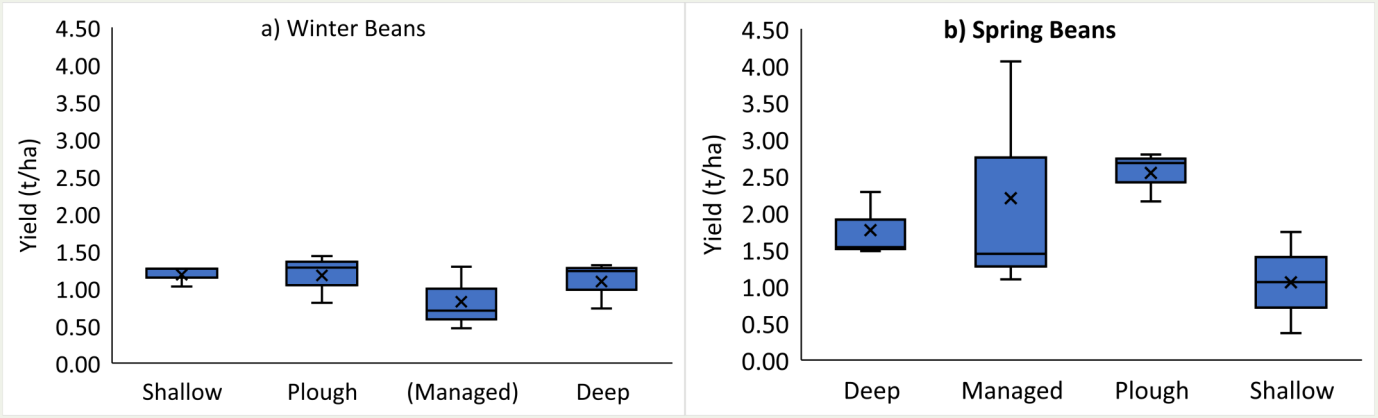

Figure 3: Box and Whisker plots for (a) winter and (c) Spring Beans in STAR Year 16 (2020/21) The central line of each box refers to the median, whereas the top and bottom edges refer to the 25th and 75th percentiles . The X in each box refers to the mean value. The bracketed treatment are winter beans, the rest are spring beans.

with previous seasons, crop yield for the continuous winter wheat was determined through the use of a specialist plot combine to take representative cuts in the plots. However, due to the variable performance in the winter and spring cropping it was decided that taking whole plot measurements using the farm's commercial combine was best to reflect the performance of the crop rather than taking a representative cut with the plot combine which may not have captured the variability of the crop. The combine yield map had been calibrated and the yield was also taken over a weighbridge to verify the yield map. In the winter and spring cropping rotations the beans performed poorly with a mean yield of 1.07 t/ha and 1.89 t/ha, respectively. A box and whisker plot for the winter and spring cropping (Figure 3) shows that the winter cropping yielded reasonably consistently between cultivation approaches, regardless of either the winter or spring beans. The largest variation resulting in the Managed approach. The spring rotation, all spring beans, resulted in much greater variation with the plough tillage attaining the highest and most consistent yields. Again, the managed approach showed the most variable yields. Winter wheat yields in the continuous wheat rotation were not significantly affected by cultivation (P=0.332), with a mean yield of 9.02 t/ha.

Summary financial analysis from the 2020-21 season are presented in Table 4. The resulting poor performance of both the winter and spring cropping resulted in low margins. In the case of winter cropping, a high negative margin, in most treatments resulted where redrilling with spring beans occurred due to the additional associated costs of spring bean seed and drilling operations. The only small, positive margin were in spring beans in the plough tillage or managed approach (£81/ha—£139/ha). The continuous winter wheat margins were between £1197/ha and £1331/ha (mean £1246/ha) with an additional premium paid on achieving 12.0% to 12.5% protein across all establishment systems. With regards to grain quality (data not shown), no significant difference to grain protein (P=0.171), TGW (P=0.294) and specific weight (0.986) were seen between any cultivation approach.

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 2020/21, resulted in poor performance of the bean break crop. Met Office anomaly rainfall maps for April 2021 rainfall was around 0% of the 1991–2020 average resulting in low and variable yields of the winter and spring beans. The yield of the continuous wheat, however was good, averaging 9.02 t/ha regardless of cultivation approach.

Margin reflected yield with the highest yield and margin obtained with shallow tillage in the continuous wheat. Poor margins in the beans reflected the difficult season and mirrors the dilemma farmers face on Beccles/Hanslope clay soils in achieving reliable, consistent performance from pulses in their rotation.

The monitoring of the three year herbal ley will continue in the coming two seasons, to assess potential for improved performance after returning to an arable rotation in autumn 2021 and monitoring the impact in winter wheat performance (1st and 2nd WW). 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 as part of their research studies with the recent successful completion of a thesis on deep seated soil compaction.

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.

Due to Covid-19 restrictions the field day was replaced with an online seminar held on 27th May 2021. Topics covered included growing pulses in rotation and integrating herbal leys in arable rotations. Two further 'soil' themed presentations focused on deep-seated compaction and advice on soil management with regards to cultivation choices to maintain soil structure and resilience. 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:

- 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)
- CropTech 2020 'Quantifying and alleviating subsoil compaction in arable soils' – November 2020
- IAgriE 2021 'Quantifying and alleviating subsoil compaction in arable soils' – January 2021

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 Power Harrow (x1) Mzuri Drill	Plough Power Harrow (x1) Mzuri Drill	N/A	Plough Power Harrow (x2) Weaving Drill
Man-aged	Broadcast Plough Power Harrow (x1)	Sumo (20 cm) Power Harrow (x1) Mzuri Drill	N/A	Sumo (10 cm) Power Harrow (x1) Weaving Drill
Shallow	Sumo (10 cm) Power Harrow (x1) Mzuri Drill	Sumo (10 cm) Power Harrow (x1) Mzuri Drill	N/A	Sumo (10 cm) Power Harrow (x1) Weaving Drill
Deep	Sumo (20 cm) Power Harrow (x1) Mzuri Drill	Sumo (20 cm) Power Harrow (x1) Mzuri Drill	N/A	Sumo (20 cm) Power Harrow (x1) Weaving Drill

APPENDIX B: COST AND MARGIN BREAKDOWN

Appendix Table 2a: STAR cost and margin breakdown 2020/21 (winter cropping)

	Shallow Till	Deep Till	Managed App	Annual Plough
	W(S) Beans			
Yield (t/ha)	**1.19**	**1.09**	**0.82**	**1.18**
Price (£/t)	**230**	**230**	**230**	**230**
OUTPUT (£/ha)	**273.70**	**250.70**	**188.60**	**271.40**
VARIABLE COSTS:				
Seed (W Beans)	90.00	90.00	90.00	90.00
Seed (S Beans)	171.00	171.00		171.00
Fertiliser	0.00	0.00	0.00	0.00
Sprays	169.00	169.00	104.82	169.00
Other				
VARIABLE COSTS (£/ha)	**430.00**	**430.00**	**194.82**	**430.00**
GROSS MARGIN - (£/ha)	**-156.30**	**-179.30**	**-6.22**	**-158.60**
FIELD OPERATIONAL COSTS (£/ha)				
Plough			61.00	61.00
Deep Sumo		41.00		
Shallow Sumo	29.00			
Power Harrow (x1)	37.00	37.00	37.00	37.00
Double press				
Single Pass Drill				
Combi Drill				
Tine Drill				
Claydon Drill	32.70	32.70		32.70
Cultivator Drill	28.00	28.00	28.00	28.00
Rolls				
Quad				
Fertiliser (x2)				
Sprayer (x8 or x5)	32.40	32.40	20.25	32.40
Total Field Operational Costs (£/ha)	**159.10**	**171.10**	**146.25**	**191.10**
MARGIN MINUS COSTS (£/ha)	**-315.40**	**-350.40**	**-152.47**	**-349.70**

Appendix Table 2b: STAR cost and margin breakdown 2020/21 (spring cropping)

	Shallow Till	Deep Till	Managed App S Beans	Annual Plough
Yield (t/ha)	**1.06**	**1.76**	**2.20**	**2.54**
Price (£/t)	**230**	**230**	**230**	**230**
OUTPUT (£/ha)	**243.80**	**404.80**	**506.00**	**584.20**
VARIABLE COSTS:				
Seed	171.00	171.00	171.00	171.00
Fertiliser	0.00	0.00	0.00	0.00
Sprays	119.28	119.28	119.28	119.28
Other				
VARIABLE COSTS (£/ha)	**290.28**	**290.28**	**290.28**	**290.28**
GROSS MARGIN - (£/ha)	**-46.48**	**114.52**	**215.72**	**293.92**
FIELD OPERATIONAL COSTS (£/ha)				
Plough				61.00
Deep Sumo		41.00	41.00	
Shallow Sumo	29.00			
Power Harrow (x1)	37.00	37.00	37.00	37.00
Double press				
Single Pass Drill				
Combi Drill				
Tine Drill				
Claydon Drill	32.70	32.70	32.70	32.70
Cultivator Drill				
Rolls				
Quad				
Fertiliser				
Sprayer (x6)	24.30	24.30	24.30	24.30
Total Field Operational Costs (£/ha)	**123.00**	**135.00**	**135.00**	**155.00**
MARGIN MINUS COSTS (£/ha)	**-169.48**	**-20.48**	**80.72**	**138.92**

Appendix Table 2c: STAR cost and margin breakdown 2020/21 (continuous wheat)

	Shallow Till	Deep Till	Managed App	Annual Plough
	W Wheat			
Yield (t/ha)	**9.34**	**8.92**	**8.67**	**9.14**
Price (£/t)	**200**	**200**	**200**	**200**
OUTPUT (£/ha)	**1868.00**	**1784.00**	**1734.00**	**1828.00**
VARIABLE COSTS:				
Seed	108.00	108.00	108.00	108.00
Fertiliser	138.00	138.00	138.00	138.00
Sprays	152.10	152.10	152.10	152.10
Other				
VARIABLE COSTS (£/ha)	**398.10**	**398.10**	**398.10**	**398.10**
GROSS MARGIN - (£/ha)	**1469.90**	**1385.90**	**1335.90**	**1429.90**
FIELD OPERATIONAL COSTS (£/				
Plough				61.00
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				
Quad				
Fertiliser (x3)	21.00	21.00	21.00	21.00
Sprayer (x6)	24.30	24.30	24.30	24.30
Total Field Operational Costs (£/	**139.30**	**151.30**	**139.30**	**208.30**
MARGIN MINUS COSTS (£/ha)	**1330.60**	**1234.60**	**1196.60**	**1221.60**