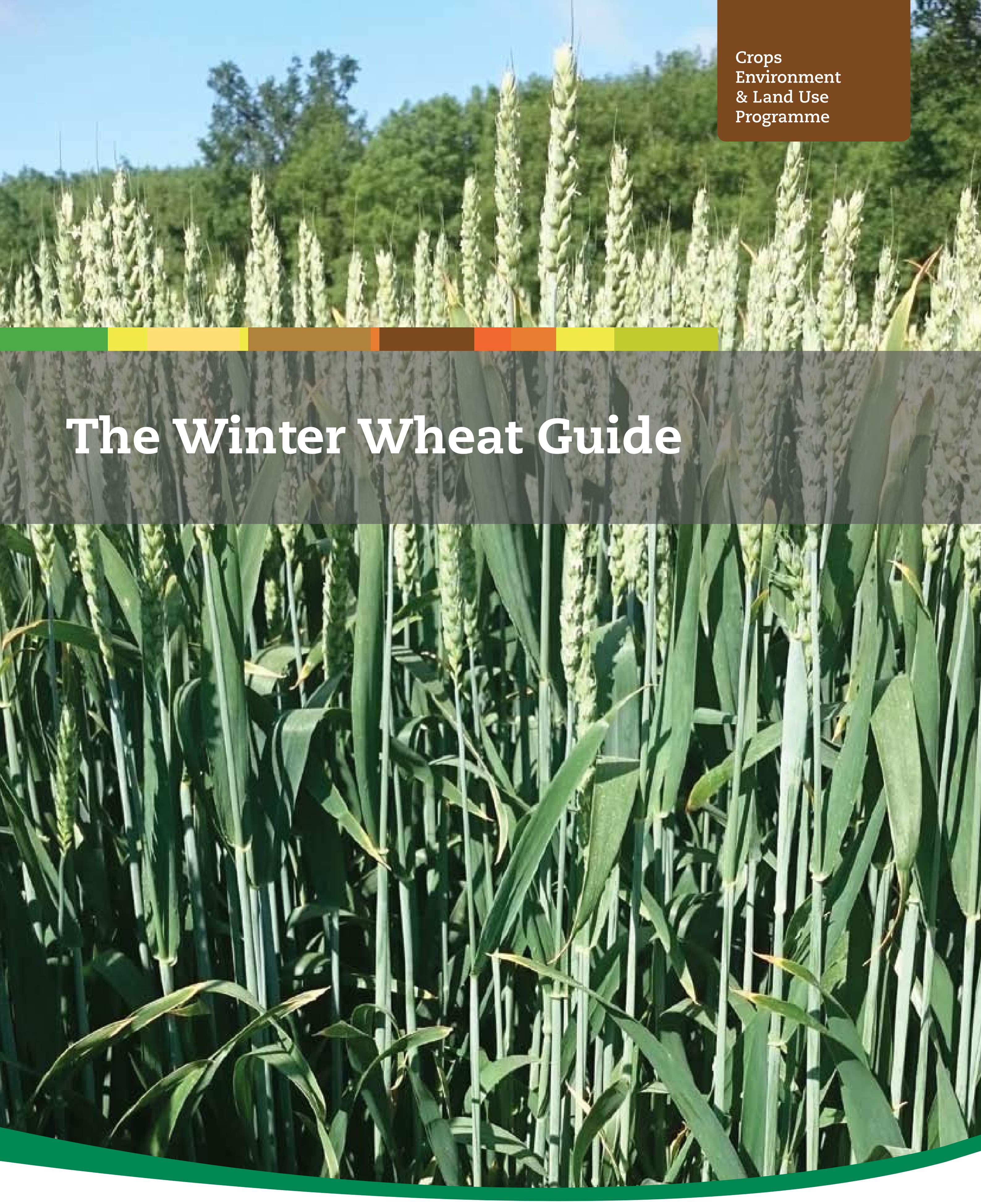
Crops
Environment
& Land Use
Programme

The Winter Wheat Guide



Teagasc

Agriculture and Food Development Authority

FOREWORD

Cereal growers are well aware of the difficulties of running their businesses when the final price received is significantly affected by world demand and production, resulting in significant price volatility. Whilst there are some market tools that growers can employ in order to try and manage that volatility, their effects are limited.

Given that growers have limited control over the end price it is essential that they minimise their costs of production as far as possible. A significant research effort goes into providing the most up-to-date and accurate information for growers and advisers to achieve this. This guide is based on detailed monitoring of winter wheat crops to understand better how yield is formed and brings together a large body of Teagasc crop production research carried out over recent years. It has been produced as part of a DAFM Research Stimulus funded project 'CIVYL', led by Teagasc with AFBI monitoring crops in Northern Ireland, and is therefore representative of wheat grown on the island of Ireland.

I trust this will be of use to the industry both north and south of the border in maximising farm profitability in the coming years.

Professor Gerry Boyle

Director, Teagasc

CONTENTS

MANAGING THE CROP TO MAXIMISE RETURN

Introduction

The average yields of winter wheat achieved by Irish growers are amongst the highest globally. This is facilitated by the mild, wet climate and long summer days which results in slow crop development, and a long grain filling period rarely affected by drought.

The crops development through its growth stages is primarily influenced by temperature, while the amount of growth the crop accumulates is mainly driven by the amount of solar radiation intercepted and converted into biomass.

Wheat, like all cereals, progresses through two main phases of development during its life cycle: vegetative development and reproductive development.

During vegetative development, the plant builds its leaf and stem architecture, the canopy, to intercept as much radiation as possible.

Once the plant moves into reproductive growth, radiation captured by the canopy is used in the production of assimilate, which is transported to the ear and stored in the grain.

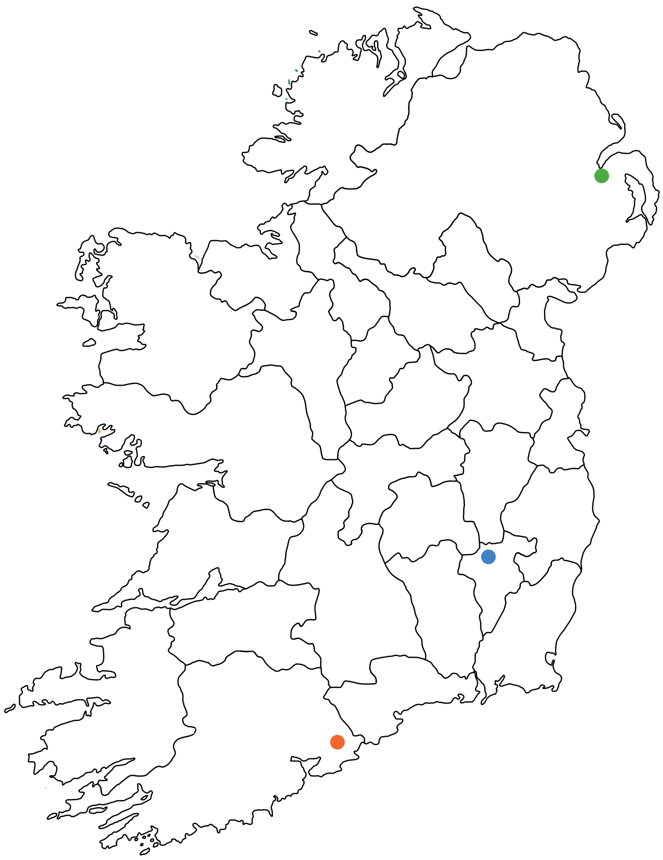
The relationship between canopy growth and radiation interception follows the law of diminishing returns. Therefore, the production and protection of excess canopy above the optimum will incur an unnecessary cost, and reduce the financial return from the crop.

Understanding the status, in terms of growth and development, of a growing crop and how it is developing allows wheat growers to optimise their crop management and maximise return.

This guide is separated into two sections: The first describes the growth and development of nine medium-high yielding crops grown across Ireland between 2013 and 2015, with average figures that can be used as a reference to compare with crops grown nationally. The second section summarises the most up-to-date information available on the key crop husbandry decisions a grower must consider when adjusting crop management.

Crop Growth and Development

The information detailed on pages 3-13 was derived from data collected from frequently monitored reference crops of the variety “JB Diego” that were grown in Cork, Carlow and Down during three growing seasons from 2013 – 2015.



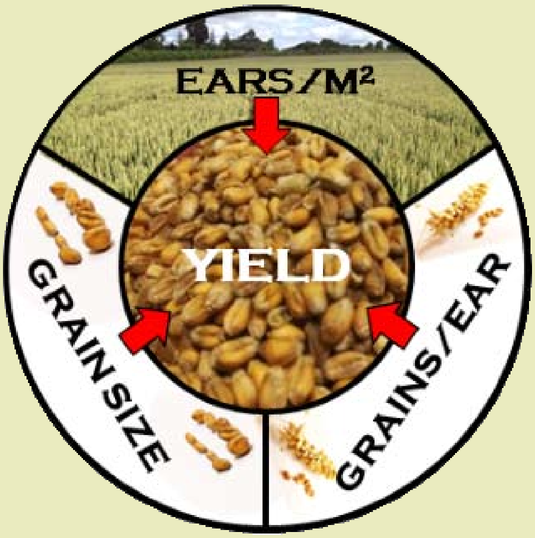
- Killeagh, Co. Cork
- Oak Park, Co. Carlow
- Crossnacreevy, Co. Down

Most crops were sown in mid-October (earliest 14th October), while some were later due to weather delayed field operations (latest December 4th). They were subsequently managed to maximise yield. Leaf and tiller production, biomass accumulation, canopy size and senescence, radiation interception and yield components were all recorded. The averages, and range of values, of these data are presented in **bold** in the following sections.

It is important to note that these averages should not be considered targets for crop growth, but rather as guides against which the progress of a particular crop can be compared to assess its status compared to normal progress. Crop development and growth can differ with variety, season and sowing date, and many other factors.

Crop Management

Pages 14-36 of this guide provide the most up-to-date information available on important agronomic considerations for Irish growers, including crop establishment, nutrient management, disease, pest and weed control, and grain quality. This information can be used to adjust management to achieve a greater yield, or to reduce the cost of producing this yield. The information in this section is based on the regulations as they apply in the Republic of Ireland at the time of writing. Similar, but slightly different, regulations exist in Northern Ireland which should be referred to if the guide is being used in that jurisdiction.



What determines wheat yield?

- Data indicated that grain number/m^2 and grain size, had an equal influence on the yield of the reference crops.
- Ear number had the biggest influence on grain number but the crop can compensate to some extent for low ear numbers by increasing grain number per ear and increasing grain size.
- However, to achieve exceptional yields, wheat crops need optimum growing conditions throughout the season to enable strong vegetative growth, ear growth and development and grain filling.

LEAF EMERGENCE AND TILLERING

Key Facts

- The rate of leaf emergence is determined by thermal time.
- Tiller survival influences final ear number which has a major influence on yield.
- The first tiller emerges as the third leaf emerges.

Leaf Emergence

Leaves are the primary organs that intercept incident solar radiation which enables crop growth by photosynthesis.
Leaf emergence is the first indicator of crop development and is determined by thermal time. For a given crop, each leaf will emerge at a consistent number of degree days (phyllochron) after the previous one. The phyllochron is calculated in °C days above a base mean daily temperature of 0°C.

The phyllochron is typically shorter in later-sown crops or crops grown in cooler seasons, and can vary slightly with site and variety.

Average Phyllochron = 110°C days
range: 89-131 °C days

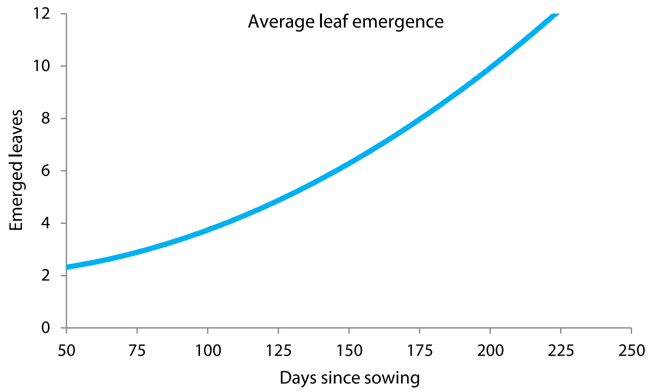
Average days per new leaf in January = 20

Average days per new leaf in May = 10

Site	Average daily temperature (°C)*			Average days per new leaf		
	Jan	Mar	May	Jan	Mar	May
Malin	5.9	6.9	10.5	18.6	15.9	10.5
Belfast	5.1	6.9	11.2	21.5	15.9	9.8
Dunsany	4.7	6.4	10.5	23.4	17.1	10.5
Dublin	5.3	6.8	10.9	20.7	16.2	10.1
Carlow	5.5	7.3	11.5	20.0	15.1	9.6
Wexford	6.0	7.1	11.1	18.3	15.5	9.9
Fermoy	5.4	7.0	11.1	20.4	15.7	9.9

*30 year mean of 1981-2010, ROI data courtesy of Met Éireann.

The consistent nature of the phyllochron allows a grower to predict with good accuracy the duration before a new leaf emerges. This can be a valuable tool when tracking the development of the crop, especially when predicting the occurrence of the ideal stage for fungicide sprays.



Leaf Number

The total number of leaves that emerge on the main stem can vary slightly with variety, site and season, with a lower number of leaves tending to emerge on later sown crops.

Average leaf number = 11, range: 10-12

Average date of flag leaf emerged = 23rd May

range: 15th-31st May

Monitoring the emergence of the final three leaves of the wheat crop is of great importance in targeting plant protection sprays at the ideal stage of development.

Tillering

Tillers are shoots which originally develop in axils of leaves on the main stem and can subsequently develop from older tillers. Each tiller initially has the potential to develop an ear and produce grain. However, usually only a proportion of tillers survive to this stage due to limited resources for sustaining their growth.

Tiller emergence typically begins as the third leaf emerges. The amount of tillering is dependent on climatic factors such as temperature and photoperiod, and crop factors such as plant populations, nutrient availability etc.

The maximum tiller number generally occurs around the early stem extension stage and can vary greatly with site and season. In some cases further tillers may develop beyond this stage, especially after plants are exposed to a period of stress such as drought or nutrient deficency.

Average tillers/plant at stem extension = 4.3
range: 3.3-5.3

Average maximum shoot number = 788/m²
range: 543-1052/m²

Final Ear Number

The number of ears present at harvest has a major influence on the yield of winter wheat. In most cases, this number is finalised around anthesis, with the proportion of shoots that survive during the period from stem extension to anthesis having a large effect.

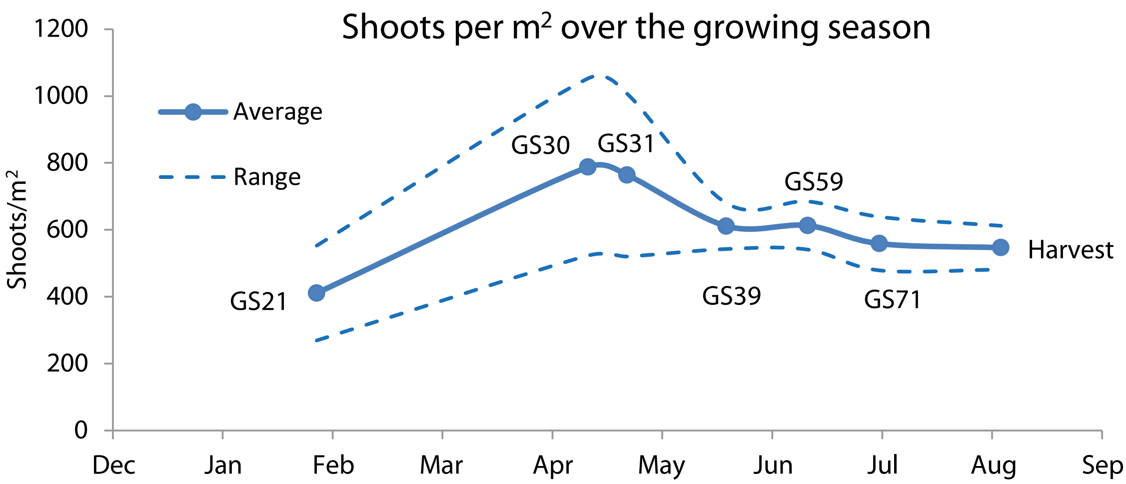
Average shoot survival = 63%
range: 50-76%

Crops that achieve very high shoot numbers at stem extension do not always achieve similarly high ear numbers and yield. Unfavourable conditions for shoot survival, such as deficiencies in nutrients or water, can result in high tiller death. The remaining tillers may also be potentially lower yielding than crops that achieve moderate shoot numbers and a high rate of tiller survival.

Average final ear number = 540/m²
range: 480-600/m²

Key husbandry factors

- Estimates of leaf emergence (i.e. phyllochron) allow increased accuracy in targeting fungicide timings.
- Nutrient deficiencies during stem extension can increase tiller death, reducing ear number and yields.
- Crops with a high ear number achieved highest yields, so target ear numbers between 550-650/m²



CANOPY FORMATION AND RADIATION INTERCEPTION

Key Facts

- The formation of a canopy determines the degree of radiation interception by the crop.
- Radiation interception influences the amount of dry matter produced by the crop.
- Canopy is measured as the ratio of green material present to the ground area it covers; Green Area Index (GAI).
- Canopy management can have a large influence on crop yields.

Canopy Formation

The development of an optimal canopy, comprising leaves and stems, is a critical part of wheat production as it enables the interception of the majority of incident radiation, which is central to dry matter production.
During the early stages of leaf emergence and tillering, canopy size increases slowly as cool winter temperatures slow the emergence of leaves and low radiation levels limit potential growth.

Average GAI at start of tillering (GS21) = 0.1 range: 0.02-0.20

By the start of stem extension the crop has produced most of its tillers and the canopy is expanding at an increased rate.

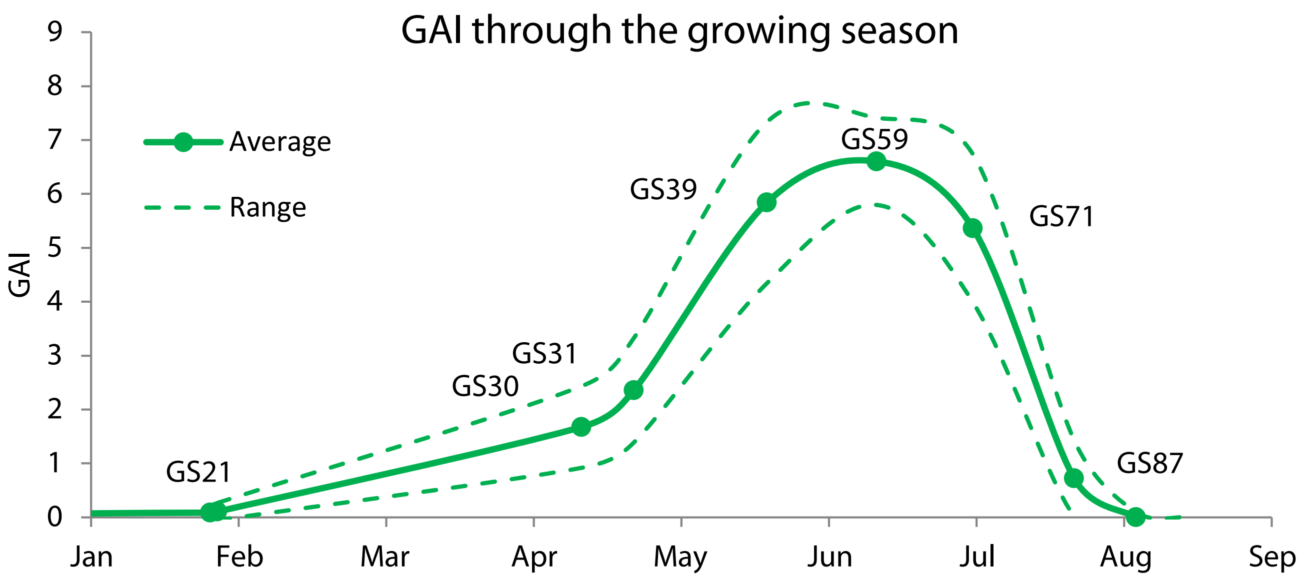
Average daily GAI increase during tillering (GS21-GS30) = 0.02/day

Average GAI at start of stem extension (GS30) = 1.7, range: 0.9-2.4

During stem extension canopy expansion is rapid as stems elongate and the final four leaves emerge to contribute a large portion of green area. Ear emergence further increases the canopy which typically reaches a maximum size around anthesis.

Average daily increase in GAI during stem extension (GS30-GS39) = 0.11/day

Average maximum GAI = 6.6, range: 5.8-7.4



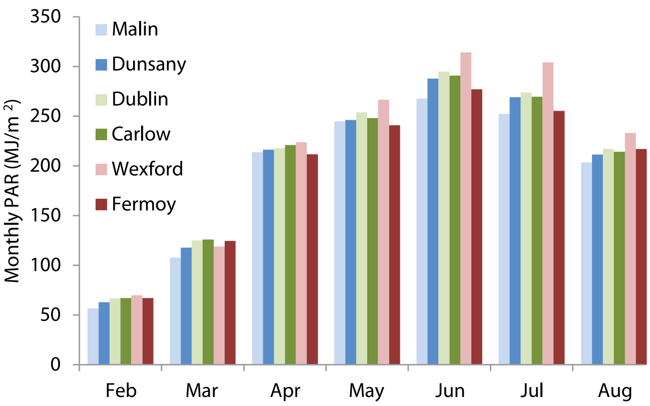
After ears have emerged and stems are fully extended, canopy expansion ceases and the amount of green canopy begins to decline due to senescense. During this period the majority of radiation intercepted by the canopy is used for the production of assimilate to fill grains in the ear. The decrease in canopy can be hastened by the onset of foliar disease, drought or by warm temperatures.

Average daily decrease in GAI post-maximum (GS59-GS87) = 0.14/day

Average GAI at GS87 = 0.7, range: 0.1-1.4

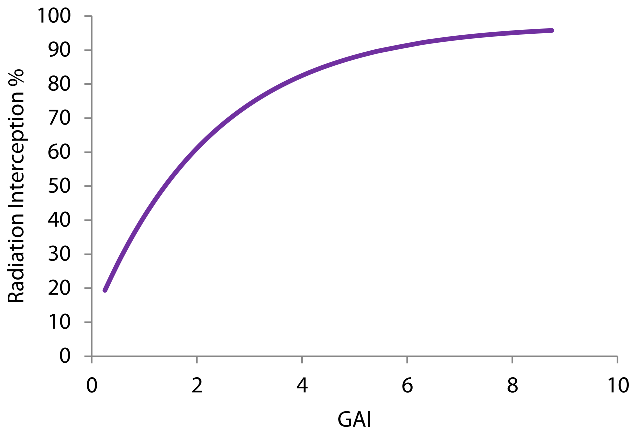
Radiation Interception

The amount of incident radiation can vary with site and season in Ireland. Generally, incident radiation increases during the spring to a peak around June and July.



*3 year mean of 2012-2015, data courtesy of Met Éireann. PAR = Photosynthetically active radiation

The proportion of radiation that can be intercepted increases as its canopy expands. However increases in canopy size above 6.5 GAI generally only provide small increases in radiation interception.



Average radiation interception GAI 5.5 = 90%
Average radiation interception GAI 6.5 = 93%
Average radiation interception GAI 7.5 = 95%

The amount of radiation intercepted by the crop after flowering has a strong influence on the thousand grain weight (TGW) at harvest. TGW has a major impact on the crop's yield. Therefore, optimum canopy management is key to maximising wheat yield at harvest.

Key husbandry factors

- Very low plant numbers can limit the potential canopy size and restrict potential growth.
- Minimise weeds that compete with wheat crops for radiation.
- Prevent nutrient deficiencies to ensure no restrictions to canopy expansion.
- Protect the canopy by minimising disease through variety selection and targeted fungicide sprays.

BIOMASS PRODUCTION AND PARTITIONING

Key Facts

- Wheat biomass production is driven by the radiation intercepted by the crop.
- The rate of crop growth (i.e. biomass produced per day) increases as the crop develops.
- The majority of biomass production post-flowering is allocated to the grain.

Leaf Emergence and Tillering

The amount of biomass production is influenced by the amount of radiation intercepted by the crop.

When canopy sizes are small and radiation is low during the winter and early spring, biomass is produced at a slow rate, with an average growth rate of 0.02 t DM/ha/day between GS21 and GS31.

Average total biomass GS31 = 2.2 t DM/ha
range: 1.1-3.3 t DM/ha

Growth during early development is mainly by leaf formation. During tillering, stem biomass production increases to a rate comparable to leaf biomass production.

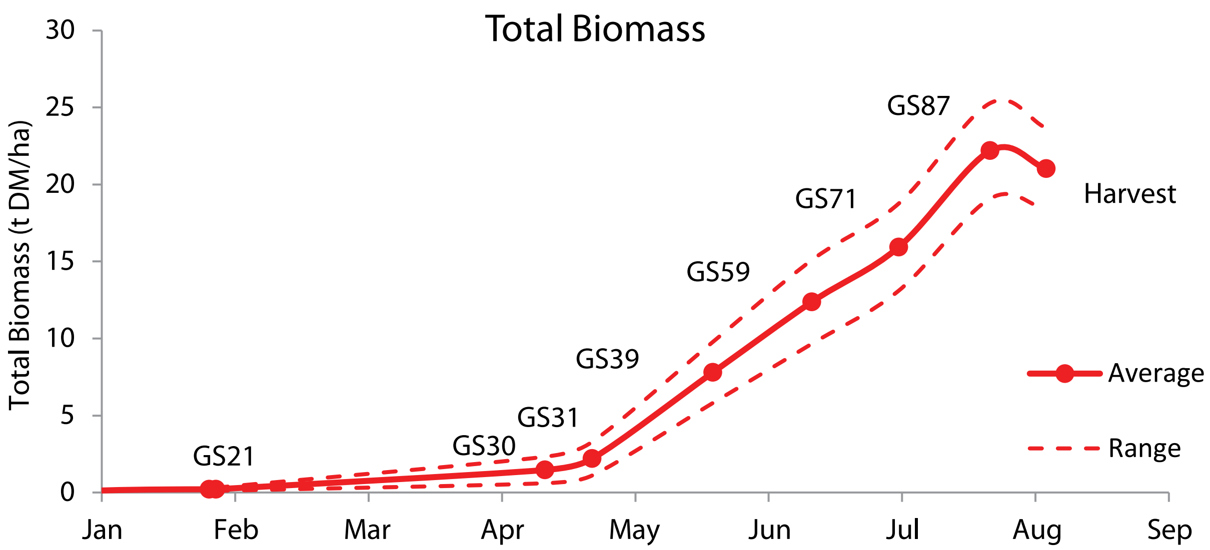
Average leaf:stem biomass ratio GS21 = 9.0:1
Average leaf:stem biomass ratio GS31 = 1.3:1

Stem Extension and Ear Emergence

After GS31 biomass is accumulated at a much higher rate due to rapid canopy expansion and increasing radiation levels during late spring and early summer. An average wheat crop accumulates 0.2 t DM/ha/day between GS31 and GS59.
The majority of biomass produced during this period is allocated to the stem as the final leaves emerge and the shoot internodes begin to extend. After GS39 leaf biomass begins to decrease, leaf production has ceased and lower leaves begin to die.

Average leaf: stem biomass ratio GS39 = 0.5:1

After GS39 biomass accumulating in the developing ears significantly increases while stem biomass continues to accumulate.



Average total biomass GS59 = 12.4 t DM/ha
range: 9.7-15.1 t DM/ha

Average ear biomass GS59 = 1.9 t DM/ha
Average stem biomass GS59 = 7.7 t DM/ha
Average leaf biomass GS59 = 2.6 t DM/ha

Grain Filling

Biomass accumulation continues at a high rate after GS59, as the canopy reaches its maximum size and radiation levels are at their highest. An average crop accumulates 0.24 t DM/ha/day between GS59 and GS87.

After GS59 some stem biomass accumulates further, however this ceases before GS71. The vast majority of biomass accumulation after GS59 occurs in the ear as assimilate is produced by the crop and transported to the grain for storage. Between GS71 and GS87, ear biomass increases at an average rate of 0.4 t DM/ha/day.

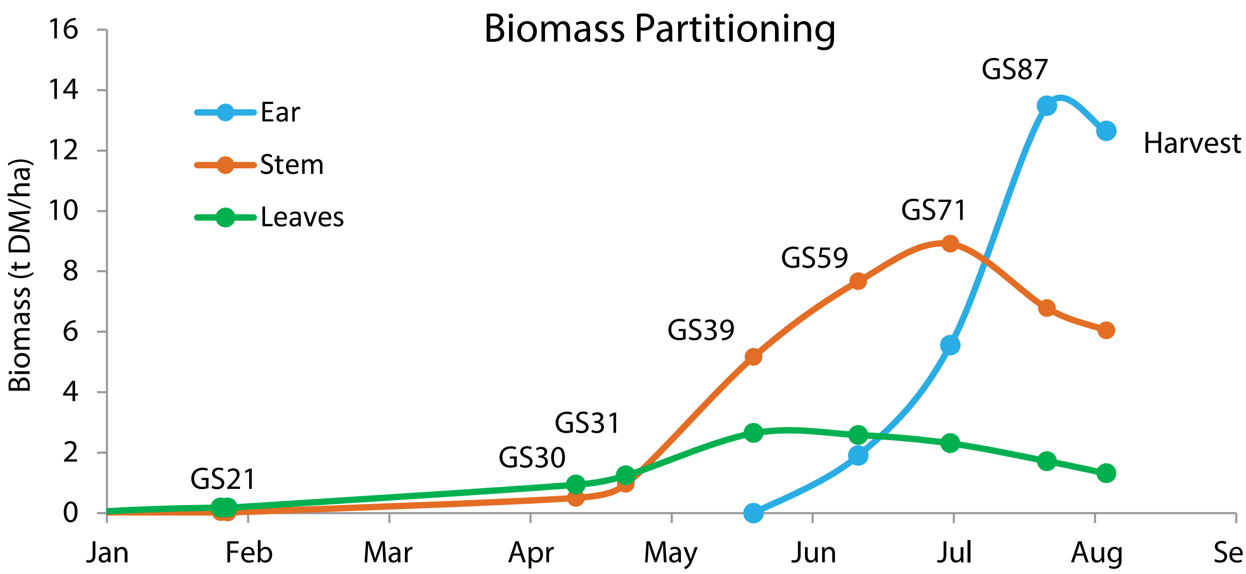
Average ear biomass GS87 = 13.5 t DM/ha
Average stem biomass GS87 = 6.7 t DM/ha
Average leaf biomass GS87 = 1.7 t DM/ha

Total biomass reaches a maximum around GS87 as grain filling ceases. A small degree of biomass loss then occurs, due to some leaf loss and plant respiration.

Average total biomass GS87 = 22.2 t DM/ha
range: 19.1-25.3 t DM/ha

Average final biomass = 21.0 t DM/ha

Approximately 6 t DM/ha of stems are present at harvest but only a proportion is available to harvest as straw, the rest being stubble.



CROP HEIGHT

Key Facts

- The largest increase in crop height occurs between the start of stem extension and flowering.
- Crop height is an important factor in the lodging risk of a crop.

Stem Extension

Prior to stem extension, the growing point of the wheat plant remains at ground level. During this period the risk of frost damage is relatively low.

Average crop height at GS31 = 15 cm
range: 10-19 cm

During stem extension the height of the crop rapidly increases. The growing point has moved above ground by this stage, and is susceptible to frost damage. In general, wheat crops are treated with plant growth regulators (PGRs) during this period to limit the degree of stem extension.
By flag leaf emergence (GS39) the height of the crop has increased to 70% of its final height.

Average crop height at GS39 = 51 cm
range: 44-58 cm

Stem elongation continues to occur until after flowering, when the crop has reached approx. 94% of its final height. Some small increases can occur during the grain filling period.

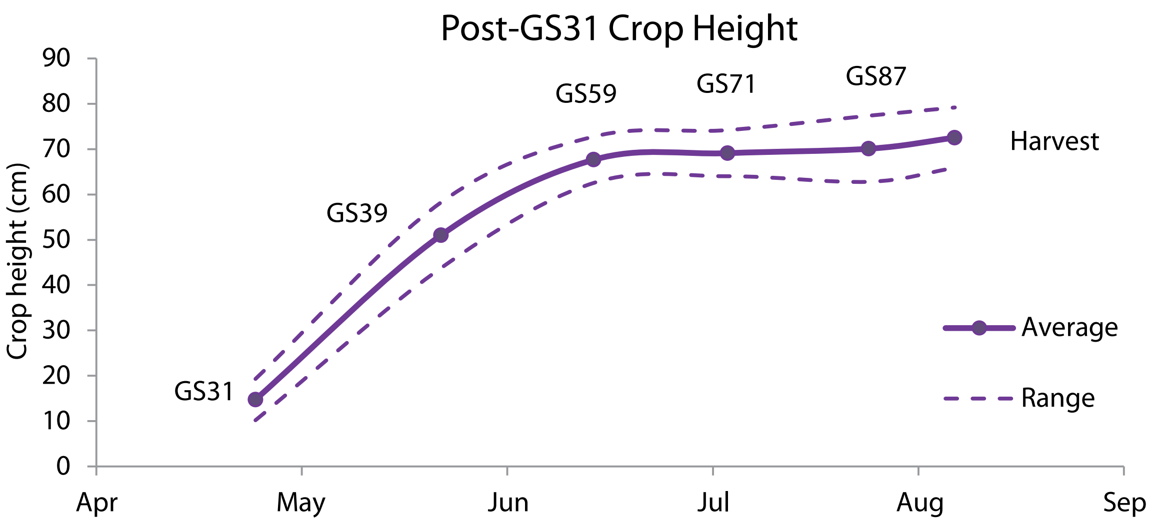
Average crop height at harvest = 73 cm
range: 66-79 cm

Height and Lodging

The final height of the crop is a factor in its lodging risk. Taller plants with a large ear weight exert a greater force on the base of plant which increases lodging risk, especially in wet and windy weather.

Key husbandry factors

- Excessive nitrogen can increase plant height and increase lodging risk.
- The timing of early PGR applications has a large effect on their ability to restrict crop height.
- Recommended lists rank varieties for shortness of straw and their resistance to lodging.



NITROGEN UPTAKE

Key Facts

- Lack of N supply at key stages of growth reduces yields through reduced ear number and reduced canopy production/survival.
- The rate of N uptake is low during the early stages of crop development.
- The highest rate of N uptake occurs between the onset of stem extension and flag leaf emergence.

When is N Taken Up?

A typical winter wheat crop sown in mid-October accumulates N at different rates during the growing season dependant on the phase of growth.

Sowing to GS30
Average rate of N uptake = 0.4 kg N/ha/day
range: 0.2-0.5 kg N/ha/day

Crops require relatively low quantities of N during this phase due to slow growth, with the majority of crop requirement already met by nitrogen present in the soil.

GS30 to GS39
Average rate of N uptake = 2.7 kg N/ha/day
range: 2.3-3.2 kg N/ha/day

Large increases in growth occur during stem extension and canopy expansion, resulting in the greatest rate of N uptake during the season for a typical crop. Below optimum supply of N during this phase can impact on canopy size and final ear number.

GS39 to GS59
Average rate of N uptake = 1.9 kg N/ha/day
range: 1.2-2.7 kg N/ha/day

Crops reach maximum canopy size and height during this phase, then the crop N requirement declines.

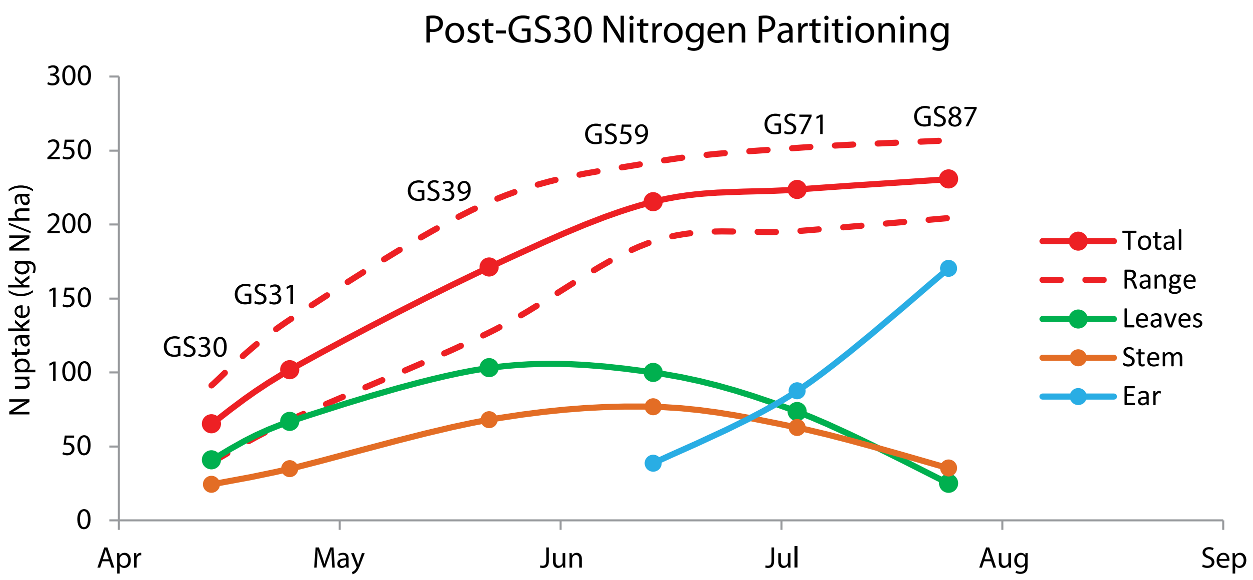
GS59 to GS87
Average rate of N uptake = 0.4 kg N/ha/day
range: 0.3-0.5 kg N/ha/day

Uptake is generally low during grain filling, with the vast majority of N allocated to grain protein formation.

Average dry grain protein content = 9.9 %
range: 8.5-11.2 %

The rate and total amount of N uptake by a wheat crop can vary substantially during the growing season. To maximise yields it is vital that N applications are managed to ensure the crop has adequate supplies during periods of high demand.

Average total N uptake = 231 kg N/ha
range: 204-257 kg N/ha
Average % of total crop N in grain = 76%



EAR FORMATION AND GRAIN FILLING

Key Facts

- Ear number and grain size both influence winter wheat yields in Ireland.
- Grain number can be limited by crop stresses, such as nutrient deficiency or drought, when the ear is forming during the stem elongation phase.
- Grain filling can be limited by hot or dull conditions during the summer and high disease incidence.

Ear Formation

The formation and maintenance of a moderate number of ears per m^2 is key to maximising the yield of winter wheat crops in Ireland.

Average final ear number = 540/m^2
range: 480-600/m^2

Wheat crops with lower than optimum ear numbers can occasionally achieve good yields through a high number of grains per ear. The number of grains present on an ear is generally related to the dry weight of the ear.

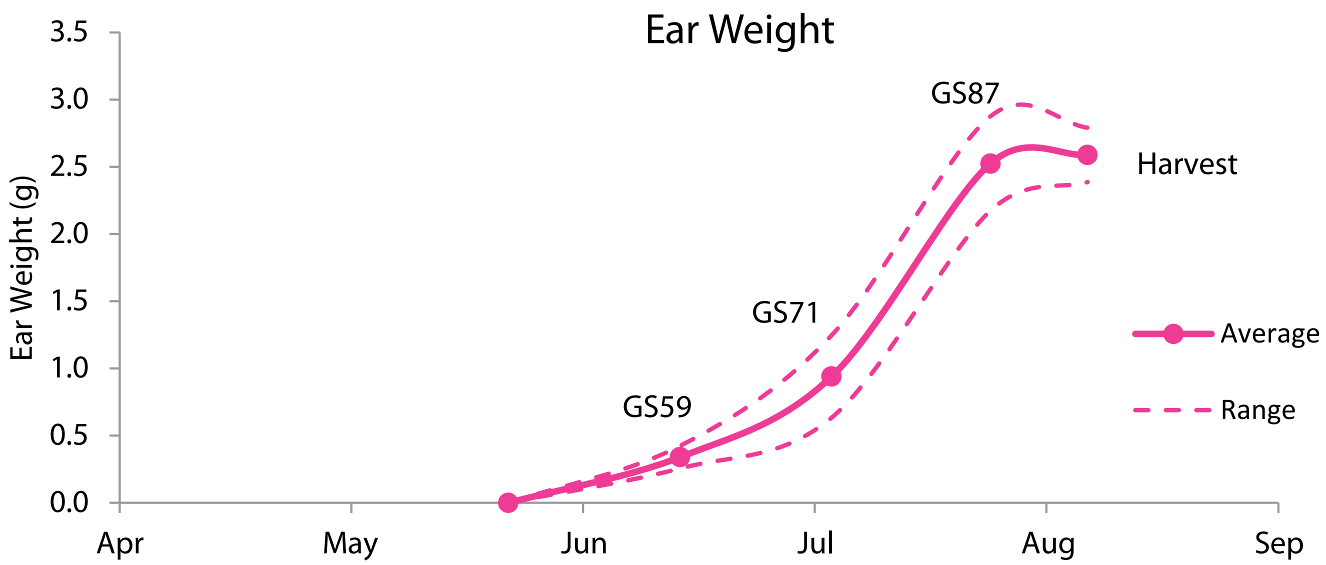
Average grains per ear = 46
range: 41-51

Ear formation occurs relatively quickly during stem extension and booting (GS30-49). Crop stresses, such as nutrient deficiency, frost or drought, and disease during these stages of development can negatively impact ear formation and result in fewer grains per ear or even complete ear loss.

Average GS30-49 period = 40 days
range: 33-47 days

Average ear weight at GS59 = 0.34 g DM
range: 0.26-0.42 g DM

At GS59 the ear only comprises 15% of the total dry weight of the crop. However, after flowering the vast majority of crop DM accumulation occurs in the ear.



Grain Filling

During grain filling assimilate produced from photosynthesis in the leaves, stem and ears is transported to the grain and stored as starch, as is a proportion of DM produced pre-flowering which is remobilised, mainly from the stem.

The amount of assimilate produced during this phase determines the size of the grains at harvest. Grain size is a key factor that influences the yield of Irish winter wheat crops.

Average weight of a thousand grains = 51 g
range: 46-56 g

Grain filling generally begins soon after flowering and continues until much of the crop has senesced. The rate of crop senescence is influenced by the temperature during grain filling with warmer temperatures typically shortening the grain filling period.

However, good disease control is also vital to avoid premature senescing of the crop, the loss of its ability to intercept radiation, and a reduction in grain filling.

Average grain filling period = 45 days
range: 37-53 days

Average grain filling period = 753°C days
range: 665-841°C days

By GS87 the ear contributes 61% of the total dry weight of the crop. After GS87 the crop fully senesces and the moisture content of the grain declines as the crop ripens. By harvest the ear consists of 87% grain and 13% chaff, with 53% of the total wheat biomass located in the grain (harvest index).

Average harvest index = 0.53
range: 0.48-0.58

Average moisture content at harvest = 17.4%
range: 15.1-19.7%

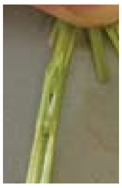
Average specific weight = 74.6 kg/hl
range: 72.2-77.0 kg/hl

Average grain yield at 100% DM = 11.1 t/ha
range: 9.6-12.4 t/ha

Key husbandry factors

- Disease control prior to flowering is vital to sustaining green leaves post-flowering and maximising the grain filling period.
- Nutrient deficiencies during stem extension can reduce ear size or result in ear loss.

WINTER WHEAT GROWTH BENCHMARKS

	**24 October (+/- 16 days) : Sowing**		**Growth Stage Description**
	27 January (+/- 32 days)		**GS21**
	Total dry weight (t/ha)	0.2	• A single tiller that has emerged from a leaf sheath is present in addition to the main shoot.
	Shoots/m^2	411	
	GAI	0.1	
	Plants/m^2	218	
	**14 April (+/- 11 days)**		**GS30**
	Total dry weight (t/ha)	1.5	• After dissecting the main shoot, the shoot apex, is located 1cm or more from the lowest point that a leaf attaches to the stem.
	Shoots/m^2	788	
	GAI	1.7	
 	**25 April (+/- 13 days)**		**GS31**
	Total dry weight (t/ha)	2.2	• After dissecting the main shoot, an internode (between nodes) greater than 1cm is present, but the internode above it is less than 2cm.
	Shoots/m^2	764	
	GAI	2.4	
	Light Interception (%)	67	
	Phyllocron (°C days)	110	
	**23 May (+/- 8 days)**		**GS39**
	Total dry weight (t/ha)	7.8	• The ligule of the flag leaf on the main shoot is visible.
	Shoots/m^2	611	
	GAI	5.8	
	Crop Height (cm)	51	
	Total leaf number	11	
	**15 June (+/- 9 days)**		**GS59**
	Total dry weight (t/ha)	12.4	• The ear is fully emerged on greater than 50% of all shoots in the crop.
	Ears/m^2	613	
	GAI	6.6	
	Crop Height (cm)	68	
	**5 July (+/- 6 days)**		**GS71**
	Total dry weight (t/ha)	15.9	• The grain contains clear liquid when pressed.
	Ears/m^2	559	
	GAI	5.4	
	Crop Height (cm)	69	
	Stem dry weight (t/ha)	8.9	
	Ear dry weight (t/ha)	5.6	
	**26 July (+/- 13days)**		**GS87**
	Total dry weight (t/ha)	22.2	• Grains are at hard dough, with dry contents, and when pressed with a fingernail the impression remains. Very little green canopy remains.
	Ears/m^2	540	
	GAI	0.7	
	Crop Height (cm)	70	
	Grainfilling period (days)	45	
	**8 August (+/- 16 days)**		**Harvest**
	Total dry weight (t/ha)	21.0	• Grain cannot be dented with thumbnail.
	Stem dry weight (t/ha)	6.0	
	Grain Weight (mg;85% DM)	51.4	
	Grain Hectolitre Weight (kg/hl)	74.6	
	Grain Number/m^2	25136	
	Grain Yield(t/ha; 85% DM)	13.0	

Crop Management

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SOIL CULTIVATION FOR WHEAT

Key Facts

- Wheat can be established using cultivation methods varying in depth, cultivation intensity, and soil inversion.
- The type and intensity of soil cultivation can impact on: crop establishment; nutrient uptake; yield; weed growth; soil structure; soil biology; greenhouse gas emissions and production costs.
- Reduced cultivation systems can have lower costs, but in our climate grass weed control and wet autumns are particular challenges.

Cultivator/drill working on ploughed ground

Cultivation Systems

There are a multitude of cultivation/establishment systems with the primary division being between inversion (plough) and non-inversion systems.

- All, but particularly non-plough systems, can vary in depth and intensity.
- Min-till systems usually deploy a stale seedbed system: stubble cultivation post-harvest to encourage weed/volunteer growth that is subsequently controlled with a herbicide.
- The depth, intensity and number of cultivation passes may vary from a single min-till pass at 75mm depth to multiple passes at depths of 150mm or more.
- Strip-till systems generally have a lead soil disturbance tine working directly in stubble at a row spacing of 300mm followed by a band or two-row seeding coulter. Some growers stubble cultivate in advance similar to a min-till system.
- Direct drill systems are low disturbance and place the seed directly in the stubble.

The Impact of Crop Establishment System

Through its impact on soil structure and seedbed, cultivation/sowing systems impact on crop establishment, growth, and yield formation. It can also affect soil water status, weed competition, the structure, biology and organic matter content of the soil, and greenhouse gas emissions. Fuel and machinery costs and work-rates are also affected.

Stubble cultivator starting a stale seedbed operation

Min-till vs Ploughing

In long-term trials, plough-based systems often established more plants than shallow min-till, but this rarely impacted on grain yield.
In wet autumns, establishment, growth and yield could be significantly reduced where min-till resulted in a poorly drained seedbeds.

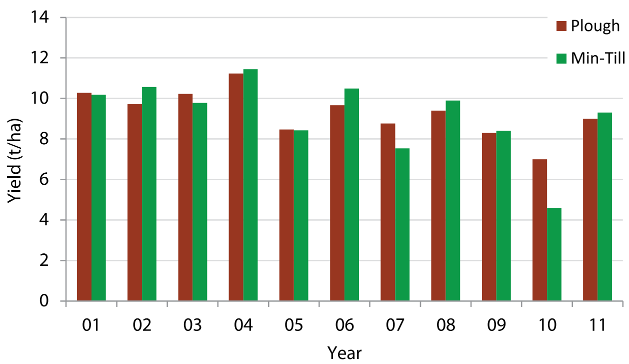


Figure 1: Wheat yields similar except in wet autumns

Earlier autumn sowing and/or deeper cultivation can reduce these risks, but at the expense of increased weed competition, more challenging autumn crop management and more expensive cultivation.
Grass weeds are challenging with non-inversion systems; sterile brome being the most difficult, often requiring combinations of crop rotation, stale seedbeds and appropriate herbicide strategies to keep numbers in check.

The loss of soil carbon in long –term tillage can be detrimental to soil structure and nutrient cycling. Low disturbance systems can reduce C loss but often the effect is redistribution of soil-C among the upper soil layers. In the Irish climate the impact of establishment system on greenhouse gas emissions is small, as the positive impact on carbon is countered by increased nitrous oxide emissions from the more moisture retentive min-tilled soil. Low disturbance systems can reduce aphid numbers and BYDV incidence, compared to ploughing while slowly increasing earthworm numbers. Slug numbers can increase also however.

Where shallow, less intensive cultivation systems are used there can be up to 50% savings in machinery costs, but this depends on the depth and intensity of cultivation.

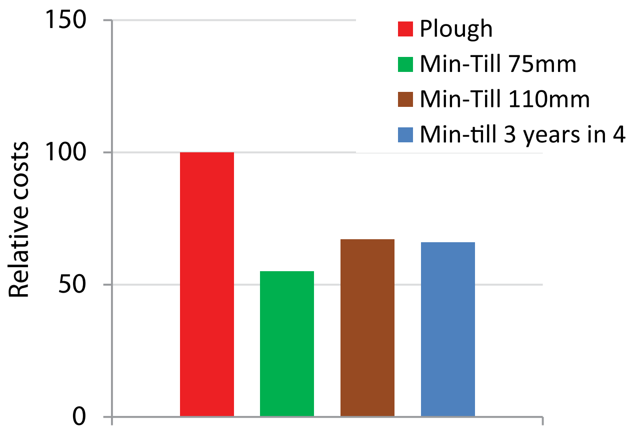


Figure 2: Min-till can reduce machinery costs.

With all establishment systems costs can be reduced by carefully matching depth and intensity to the crop needs and by adopting an appropriate ownership strategy (ownership, partnership/sharing, hire, contractor use etc).

Strip tillage drill sowing directly in stubble .

Key husbandry factors

- Protect the soil by adopting a soil management approach including traffic and axle load restrictions and low ground pressure adoption.
- Choose a cultivation system based on: soil type and condition, climate, cropping, weeds, grower skills, scale and existing machinery.
- Only cultivate when the soil is dry enough not to be damaged by the cultivator and tractor.
- Select non-inversion systems carefully and consider long-term weed control and soil structure protection. Stale seedbeds, rotations, sowing date, herbicides, cultivation depth and rotational ploughing may have a role.
- With plough and non-plough systems select cultivation and consolidation elements (tines, discs, packers/rollers etc) carefully to suit your soils and operate at a depth and intensity that achieves the desired soil conditions while avoiding over-cultivation and sub-surface compaction.

SEED RATE & ESTABLISHMENT

Key Facts

- Wheat can compensate for low plant numbers better than barley.
- Good plant establishment sets the crop up to have a high yield potential.
- Seed quality and sowing date can have large influence on plant establishment.
- Considering thousand grain weight and sowing conditions is critical when calculating seed rate.

Plant Establishment

The ability of wheat to compensate for low plant numbers is greater than barley, with economically viable yields obtained previously from crops with as low as 100 plants/m^2. This compensation typically occurs through increased tillering and the initiation of more grain sites in each ear. However, the number of wheat plants established still influences the management and yield potential of a crop, with a good establishment providing a strong foundation to maximise yields. It should also be noted that excess plant numbers increase lodging risk later in the season.

Plant establishment is primarily influenced by:

- seed quality
- sowing date and seed rate
- soil conditions after sowing
- pests, weeds and disease

Seed Quality

The quality of seed refers to its germination capacity, its purity from weed seed, seed size and the absence of disease.

All these factors have a direct influence on plant establishment and therefore should be evaluated for any seed selected to be sown by Irish wheat growers. Purchasing Certified Seed ensures that these factors are at an optimum level, due to the monitoring of seed crops and subsequently produced seed.

The **germination capacity** of seed refers to average % of seed that will germinate and begin development under ideal conditions. The standard germination capacity of wheat seed is 85%. This can be negatively affected by a range of factors including wet conditions around harvesting, the presence of ear diseases or excessive heating during drying.

Common wheat **seed-borne diseases** include bunt, ergot, Microdochium and other seedling blights and loose smut. The use of fungicide seed treatments can reduce the risk associated with these diseases. Furthermore, some seed treatment products also protect against pest damage due to the inclusion of insecticides.

Sowing Date

Planting winter wheat early (mid to late September) generally ensures good seedbeds and favourable temperatures during germination leading to higher establishment rates. However, there is an increased threat from Take-all, foliar diseases eyespot, mildew and aphids (BYDV).

Later plantings (late October to mid November) run the risk of poorer seedbeds, slower germination and emergence thereby increases the losses from pest attack (birds, slugs), and water logging, etc .

Most winter wheat varieties can be sown in early spring (mid to late February) where conditions allow but yields will be lower than autumn sown crops.

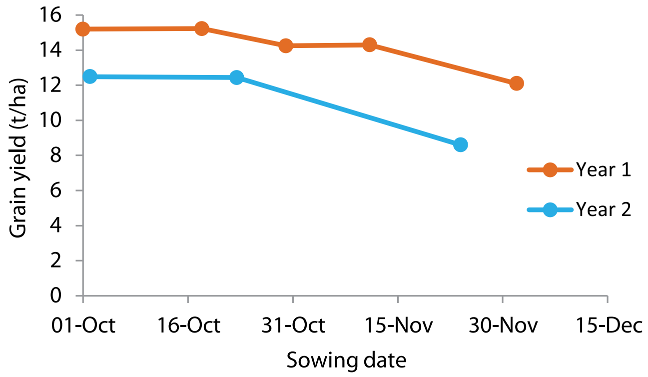


Figure 1. Effect of sowing date on winter wheat yield.

Traditional establishment methods of plough, till and sow is a very flexible method of crop establishing but lower cost systems such as non–inversion tillage (min-till, strip till, no-till) can be equally as effective as long as the seedbed conditions are good at the time of sowing.

Seed Rate

Seed rate directly impacts plant numbers. When selecting a seed rate the **thousand grain weight (TGW)**, sowing date and soil conditions need to be considered.

The TGW refers to the weight of 1000 seeds, and may be displayed on the seed packaging or may be supplied by the merchant. As seed rates are calculated by weight, a higher TGW seed will require a higher seed rate than smaller seed to achieve the same seeds/m^2.

In order to calculate seed rate, the number of desired plants/m^2 must first be decided. Later sown crops typically have higher target plant numbers, to reduce the risk of limited tillering.

Also, for a given site the % of seeds that are likely to establish should be estimated. For crops sown in September this can be as high as 90%, while it can fall to 75% by late October and 60% by late November.

Seed rate can subsequently be calculated using:

$$\text{Seed Rate (kg/ha)} = \frac{\text{Target Population x TGW}}{\text{Estimated Establishment \%}}$$

Example seed rates for certain target plants/m^2 and TGW

Sowing date	Late Sept	Late Oct	Late Nov
Target plants/m^2	240	280	300
Expected establishment %	85	70	60

TGW (g)	**Seed rate (kg/ha)**		
45	127	180	225
50	141	200	250
52	146	208	260
55	155	220	275

Rotation and Disease

Winter wheat can be one of the highest yielding crops on the farm but it needs the correct rotational position and management to realise this potential.
Grow winter wheat after grass leys or break crops (beans, beet, maize, oilseed rape, etc) for the highest yields. Take-all can significantly reduce yields in the 2nd and 3rd years after a break crop. Later sowing, lower seed rates, high soil fertility and earlier nitrogen can all help to reduce the effects of take-all.

Key husbandry factors

- Seed quality, sowing date and thousand grain weight all need to be considered when calculating seed rate.
- Sowing date has a large influence on disease, pest and yield capacity, with earlier sowing producing the highest yields.
- Carefully select the rotational position of wheat to maximise yields.

NITROGEN MANAGEMENT

Key Facts

- In wheat nitrogen (N) is critical for canopy formation and duration as well as grain site retention.
- The majority of N should be applied by GS32 to drive canopy formation and maintain grain sites.
- Efficient use of fertiliser N depends on good soil pH and optimum levels of other nutrients

Nitrogen fertiliser is the most costly individual input to winter wheat and therefore optimising its use is critical to profitable production.

How Much?

Recommended nitrogen inputs to crops in Ireland are determined using a soil N index system. The system gives an indication of the likely supply of nitrogen from the soil which in turn determines the amount of fertiliser nitrogen to be applied.

The N index of a field is based principally on the previous cropping history. Fertiliser recommendations will be higher where soil supply is likely to be lower (e.g. after continuous cereals) compared to where soil N supply is high (e.g. following ploughing of permanent pasture).

Tillage N index system

N index	Previous cropping
1	Cereals, Maize
2	Break crops, leys, 3rd or 4th crop after permanent pasture
3	1st or 2nd crop after permanent pasture
4	1st or 2nd crop after permanent pasture (grazed only)

Recommended rates for each soil N index and yield level are given on the next page. Nitrogen inputs to all crops are subject to maxima set out in SI31 of 2014.

Grain yield	9 t/ha	10 t/ha	11 t/ha
N index	N rate (kg/ha)		
1	210	230	250
2	180	200	220
3	120	140	160
4	80	100	120

Proof is required for yields above 9 t/ha; where milling wheat is being grown on contract an additional 30 kg N/ha can be applied

Timing/Number of Splits

While there may be visual effects, winter wheat generally exhibits no yield response to N applications at sowing in the autumn, irrespective of whether the N is applied as fertiliser or as organic manure. Additionally, N applied in the autumn is likely to be lost from the soil over the winter period. Nitrogen should therefore not be applied to winter wheat until the spring when growth increases.

Nitrogen is normally applied to winter wheat in two or three splits. The first application is applied just as spring growth resumes in early/mid-March when the crop is at the late tillering/early stem extension growth stage. There is some evidence to suggest that GS30 is the optimum timing for first N where take-all is not a problem. The second split is applied by around GS31 in late March/early April just before the main period of crop growth and leaf area production. There is often no yield benefit of using more than two splits but if a third split is being applied it is applied around flag leaf emergence (GS37). Where rates in excess of 150 kg N/ha are being used, a third split should be considered to reduce the risk of N loss due to adverse weather conditions after earlier applications.

The proportion of the total applied in each split is not critical as long as approx. 75-80% of the total recommended amount is applied before GS32. However in situations with high soil N supply (e.g. after grass) or in lush crops, high rates of early N can increase the risk of lodging. Alternatively, where take-all is likely more N earlier (i.e. up to 50% in the first split) can be beneficial.

Where milling wheat is being grown N fertiliser can be applied at flag leaf emergence or foliar urea may be applied at the milky ripe stage to increase protein content.

Forms of N

The initial application of N to winter wheat will often be in the form of an NPK compound. Calcium ammonium nitrate (CAN) is the main form of straight N applied to winter wheat in Ireland. Urea is normally a less expensive source of N than CAN and can give similar performance to CAN in the majority of instances. However, it is susceptible to loss of N as ammonia by volatilisation when applied to the soil surface, and this N loss can lead to reduced yields. The risk of loss can be minimised by avoiding applying urea to recently limed soils or to soils that are likely to dry out after application. Recently urea treated with urease inhibitor significantly reduces the risk of loss of N (ammonia loss) and hence the performance of urea is comparable to that of CAN on a consistent basis. It should be noted that urea is less dense than CAN and is therefore more difficult to spread evenly over wider tramlines.

Organic forms of N can also be used. Organic manures with high levels of readily available N (slurries and poultry manures) should be applied in the spring to achieve efficient N use. Timing of application of organic manures with less readily available N, such as farm-yard manure or mushroom compost, is less critical.

Key husbandry factors

- Fertiliser N requirement will depend on yield potential, site history and organic manure applications.
- Adjust the amount applied for likely soil N supply using the N index system.
- Apply in two or three splits.
- Apply most N by GS32 to drive canopy formation and maintain grain sites.

CROP NUTRITION - Lime, P & K

Soil fertility management is a key component in producing high yields of winter wheat. Soil testing is an essential component of fertility management.

Soil Testing

- Test soils once every 3 to 5 years.
- Establish soil pH, P, K, Mg, Cu, Mn & Zn levels with an S4 soil test to formulate lime and fertiliser programmes.

Figure 1. Regular soil sampling is a small annual cost and is the 1st step to the efficient use of N, P & K.

Soil pH and Lime

The ideal soil pH for winter wheat is pH 6.5; this will ensure optimum nutrient availability of both major and minor nutrients.

- Apply lime as recommended on the soil test report.
- Work ground limestone well into the seedbed before sowing.
- Don't exceed 7.5t lime/ha in one single application and where quantities in excess of this are recommended apply half in the first year and the remainder 2 years later.
- Lime will start working once incorporated into the soil. For example 35% of lime is <0.15mm which is the most reactive part of the lime in the year of application.
- Where soils are low in magnesium, apply Mg lime (Dolomitic limestone).
- Granular lime can be used to maintain soil pH but must be applied annually. This is more expensive than ground limestone. Costs should be considered over a 3 to 5 year period.

Figure 2. High yielding winter wheat has a high P and K demand.

Phosphorus (P) & Potassium (K)

The soil test will provide an estimate of the levels of plant-available P & K in the soil over the growing season.

- Phosphorus is critical in the first 6 weeks of establishment for both root and tiller development.
- Potassium plays a vital role in building more robust plants and maintaining water balance. Plant K uptake is highest during the reproductive phase.

P and K Advice

The rates of P and K required will depend on the soil test P & K reading and crop yield potential. Table 1 shows the recommended fertiliser rates of P and K for a winter wheat crop yielding 6.5t/ha. These fertiliser application rates need to be adjusted for higher grain yields. An alteration of 3.8 kg P and 10.0 kg K (relative to the values in Table 1 for P and K, respectively) is needed per 1 tonne grain yield above 6.5t/ha. For example a 10.0t/ha crop at soil P & K Index 3 will require 38kg P (10 x 3.8) & 100kg K/ha (10 x 10).

Table 1. Soil P & K Index, soil test concentration and fertiliser advice for winter wheat at 6.5 t/ha

Soil Index	Soil Test (mg/l)		Advice[1], [2](kg/ha)	
	P	K	P	K
1	0-3.0	0-50	45	95
2	3.1-6.0	51-100	35	80
3	6.1-10	101-150	25	65
4	>10	>151	0[3]	0

[1]Advice based on reference grain yield of 6.5 t/ha @ 20% MC. [2]Annual maximum soil P application rates under S.I. 31 of 2014. [3]Note, on index 4 soils with soil pH >7.0, an application of 20 kg/ha P is allowed.

Managing P & K Applications

- Soils at P and K indexes 1 and 2 have a high nutrient demand. Applications should aim to build up soil fertility to index 3 plus meet annual crop P & K requirements for yield.
- Soils at index 3 for P and K have optimum levels to maximise grain yield annually. Advice at index 3 is to replace P and K removed at harvest time (grain & straw), to maintain soil fertility.
- Soils at index 4 have a high nutrient supply and offer the opportunity to save on fertilisers. It is recommended to omit P for 2 to 3 years after which a soil test should be taken to assess soil P levels. For K omit applications for 1 year and revert back to index 3 advice until next soil test. Ensure soil pH is in optimum range for soil P & K availability.

Application and Timing of P and K Fertiliser

Recommended rates of P and K fertiliser should be determined based on soil test results and crop yield potential. On soils with very low P and K levels (i.e. index 1) it can be beneficial to apply a proportion of the P and K required at sowing time to stimulate establishment and rooting. Combined drilled P fertiliser at sowing time has been shown to be most efficient in terms of crop uptake (note: P fertilisers cannot be applied after 15th September under Nitrates Directive rules). However, the main timing for P and K applications to winter wheat is early spring time in order to replenish and build soil fertility.

Figure 3. Effect of P (-/+) on rooting and tiller development in cereal seedlings on a low P soil (Index 1).

Research has shown that a soil with a higher P index will give a higher yield irrespective of how much P fertiliser is applied to the crop (Figure 4). Therefore the objective should be to build soil P and K fertility to index 3 to maximise grain yield potential.

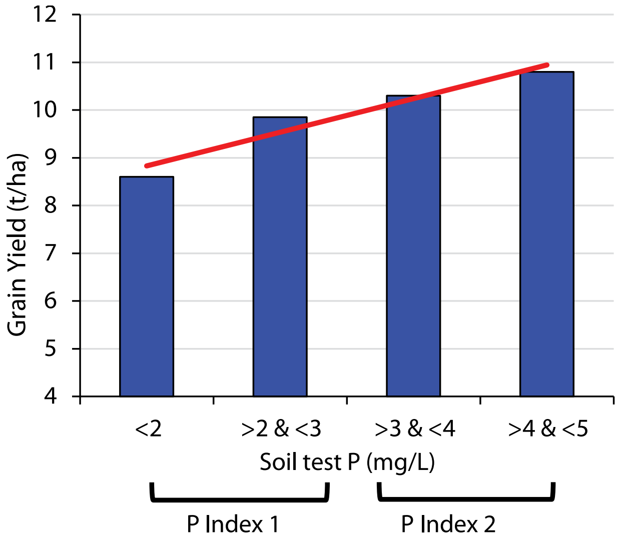


Figure 4. Average winter wheat grain yield across different soil test P concentrations (P index 1 and 2 soils).

Fertiliser Selection

Select a suitable compound fertiliser to deliver the optimum levels of P and K in the correct ratio. Where high rates of K are required apply in springtime. Examples of appropriate fertiliser programmes based on P : K blends and soil P and K indexes are shown in Table 2.

CROP NUTRITION - Lime, P, K and Micronutrients

Table 2. Fertiliser P and K advice for 10.0 t/ha target grain yield, required P:K ratio and appropriate P:K fertiliser blends

Soil Index ratio	P kg/ha	K kg/ha	P : K Ratio	P-K Fertiliser blend
1	58	130	1 : 2.4	0-10-24
2	48	115	1 : 2.4	0-10-24
3	38	100	1 : 2.6	0-8-21
4	0	0	0	0

Other Nutrients

Sulphur (S)

An adequate supply of S is very important for winter wheat crops as it is essential for the conversion of N to protein. Wheat crops grown on light to medium soil types, especially those with lower soil organic matter or in long term tillage, are most responsive to S. It is recommended to apply 15 kg/ha S with the 1st and/or 2nd split of N fertiliser.

Magnesium (Mg)

The Mg levels in the soil can be assessed by soil testing. One of the most effective methods of correcting soil magnesium fertility is by applying Mg limestone (Dolomitic limestone). Where lime is not required apply Mg-fertilisers once every 3 to 4 years.

Trace Elements

Trace elements such as copper, manganese and zinc are important for cereal production. Soil levels will depend on the soil type and such factors as high soil pH or recently limed soils. Apply trace elements where soil levels are low (below Index 3) based on the S4 tillage soil test. Table 3 shows soil index levels for Cu, Mn & Zn.

Table 3. Soil test levels for Cu, Mn & Zn (mg/l)

Soil Index	Cu	Mn	Zn
1	<1.0	<90	<1.0
2	1.01 – 1.5	90.1 - 120	1.01 – 1.5
3	1.51 – 3.0	>120	1.51 – 3.0
4	>3.0	--	>3.0

Copper (Cu)

Copper deficiency is mainly found on light textured, acidic or alkaline soils. The soil test is a very reliable indicator of soil Cu status. Copper sulphate applied to soil can be an effective option to improve soil Cu levels. Alternatively apply foliar Cu formulations where a deficiency is present.

Manganese (Mn)

Manganese is one of the most widespread trace element deficiencies in cereals (see figure 5). Deficiency can be caused by deficient soils (light to medium type soils), low availability aggravated by poor soil conditions, low soil temperatures/ moisture and loose seedbeds. Unconsolidated seedbeds will result in Mn being less available leading to Mn deficiency. The soil test is a poor indicator of Mn deficiency and therefore crops should be managed based on previous field experience. Ensure seedbeds are well consolidated and check crops regularly early in the season for symptoms of Mn deficiency. Options to control Mn deficiency include Mn treated seed, Mn added to fertilisers or foliar Mn applications.

Zinc (Zn)

Zinc deficiency is most common on light textured soils. High soil pH (>7.0) in conjunction with high soil P levels reduce Zn availability. The soil test is a very reliable indicator of a possible Zn deficiency. Zinc deficient soils can be treated with zinc sulphate. Alternatively apply foliar Zn in the early stages of crop development.

Figure 5. Manganese deficiency symptoms on the right in winter wheat. Plant on the left healthy.

Organic Manures

Organic manures (slurry / farmyard manure) are a valuable source of organic matter and can supply major and minor plant nutrients.

To maximise the fertiliser value of manures ensure the following:-

1. Mix manures well before application.
2. Check nutrient (N, P & K) content where possible.
3. Apply evenly and accurately at a consistent rate of application.
4. If applying in the autumn apply low N organic manures (FYM / Spent Mushroom Compost).
5. If using high N manures (slurries / poultry manures) on winter wheat they should be applied to the growing crop as growth resumes in the spring to maximise the nitrogen benefit.
6. Adjust bag fertiliser application rates based on manure type and rates of application.
7. Check farm fertiliser plan to determine quantity of manure import.

Table 4. Typical available N, P & K values for a range of manures

Manure type	N	P	K
Slurries	kg/m^3		
Cattle	0.7	0.5	3.3
Pig	2.1	0.8	1.9
Solid Manures			
Poultry:	kg/tonne		
Broiler litter	5.5	6.0	12.0
Layers (30% DM)	6.8	2.9	6.0
Layers (55% DM)	11.5	5.5	12.0
FYM	1.4	1.2	6.0
Mushroom Compost	1.6	1.5	8.0

- To convert kg/m^3 to units/1,000 gallons, multiply by 9.
- Above refers to **available N**, P & K in a range of organic manures. Consult with nutrient limits as per nutrient legislation (SI 31 of 2014) to determine maximum/total farm N & P limits.

Key husbandry factors

- Apply lime as recommended and maintain soil at pH 6.5.
- Apply recommended rates of P and K based on soil analysis.
- Aim to build soil P and K fertility to soil index 3 to optimize grain yield potential.
- Select a suitable fertiliser to deliver the correct balance of N, P and K.
- Apply trace elements where low soil levels are indicated on the soil test report.
- Adjust crop fertiliser requirements where organic manures are applied.

WEED CONTROL

Key Facts

- Where a weed challenge is significant, yield losses can be expected.
- Target herbicide applications at the pre-emergence and early post emergence timing (GS14-23) for maximum effect.

Crop growth and, ultimately, yield is driven by green leaf area. Weeds compete with the crop for radiation, water and nutrients, all of which can reduce the crop's ability to achieve maximum yield.

Cleavers in winter wheat

Weeds differ in their ability to compete with wheat. Wild oats, sterile brome and cleavers are the most competitive with corn marigold, poppy, fat hen, fumitory, chickweed, redshank, and knotgrass less competitive and dead nettles and field pansy least competitive. Earlier sown crops tend to have a higher weed burden than later sown crops. Wheat crops also tend to be more open that barley crops which allows more light into the base of the crop and encourages weeds to germinate over a longer period.

The yield benefits from controlling weeds can be small if the weed challenge is low but leaving weeds uncontrolled increases the overall seed burden and can interfere with harvesting. It will also lead to a greater seed return to the soil leading to increased problems in future years.

Field history, assessment of the weed species and their density is critical to achieving good control. Other factors that influence weed control include:

- crop health and growth stage
- type and size of weed
- growing conditions
- herbicide choice and rate
- correct application

Types of Herbicides

Herbicides that can be applied to wheat generally fall into the following categories:

- Residual herbicides (Pendimethalin, diflufenican, prosulfocarb, etc.) give prolonged control of germinating weeds.
- Contact herbicides must be applied to emerged weeds for best control.
- Sulfonylurea (SU; ALS) contact herbicides (Metsulfuron, thifensulfuron, iodosulfuron, etc.) control a range of weeds but are best mixed with a hormone herbicide. SUs can be slower acting than hormones but still require good growing conditions for best control.
- Hormone herbicides (CMPP, MCPA, dicamba, Fluroxypyr, Arlyex, etc) have a limited weed spectrum. Good growing conditions are necessary for best control.
- Grass weed herbicides (Isoproturon, pendimethalin, Pinoxaden, etc) can control annual meadow grass, wild oats and other grass weeds.

Generally a mix of a residual and contact herbicides are applied in autumn applications while an SU and hormone can be used for spring applications.

ALS herbicide (SU herbicides) resistance such as in corn marigold, chickweed and poppy are the most common in Ireland. Check field history and general herbicide control each year to avoid a build-up of resistant populations. Adjust herbicide programmes to include different active ingredients where resistance issues are known.

Herbicide Timing

The 4 main weed control options are:

- **Pre-drilling:** A non-selective herbicide (glyphosate) applied pre-harvest or following stubble cultivation can be used to reduce the weed population especially grass weeds such as sterile brome, annual meadow grass, scutch and black grass.
- **Pre-emergence** applications can be used in earlier sown crops for grass weed control, especially wheat established using minimum tillage.
- **Early post-emergence** herbicide application at the 2-4 leaf stage of the crop is the most commonly used. This is usually tank mixed with an aphicide.
- **Spring:** Late sown autumn crops will normally have a lower weed challenge and weeds can be controlled in the spring. Follow-up on difficult to control weeds or late germinators.

Weeds have different competition patterns e.g. cleavers can be controlled in the spring in wheat before GS31 without crop yield loss. Grass weeds including meadow grasses and wild oats will need to be controlled early, as they can compete with the crop for nutrients and radiation from an early stage.

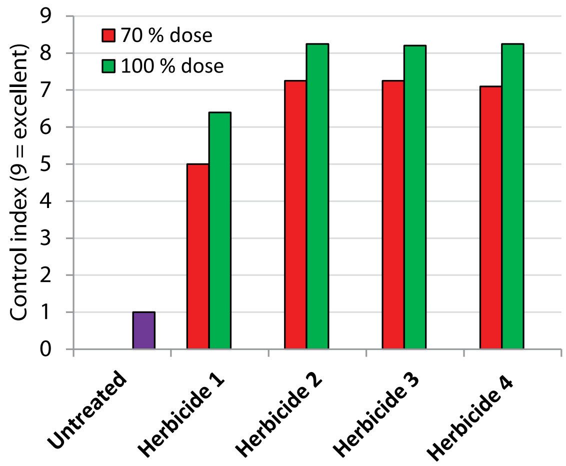
Where perennial weeds (eg. scotch/thistles) are a problem, apply glyphosate to the preceding crop for best control, where possible.

Field records will help inform herbicide selection. Match herbicide to the known weed spectrum in the field.

Post Emergence

Early post emergence applications have proven to be successful to control most weeds in winter wheat. Application of residual herbicides at GS 14-23 will give good control of small emerged weeds and the residual action will control weeds yet to emerge. However some difficult to control weeds such as fumitory, groundsel, cleavers and sterile brome may need a follow–up application in spring. Crops under stress (nutrient deficiency, water logging etc.) will compete poorly against weeds and can be adversely affected by herbicide applications.

The rate of herbicide used does not have a big effect if greater than half the recommended rates are used, particularly if used early. The results of the trial below show that reducing the herbicide rate by 30% had a small effect on the weed control, with no effect on yield.



Effect of dose on effectiveness of weed control.

Brome Control

Brome has become more problematic in recent years. All culturable control methods should be used. Chemical control using ALS herbicides is generally successful when growing conditions are excellent in April.

Key husbandry factors

- Use glyphosate to control perennial weeds in previous crops where possible.
- Use field history and weed assessment to correctly select a herbicide.
- Match post-emergence herbicide rates to the weed size. Larger weeds require higher rates.
- Use a mix of herbicide types to prevent resistance.

PEST CONTROL

Key Facts

- Aphids, leatherjackets and slugs are the main pests of winter wheat.
- Yield losses to BYDV are more likely in crops sown early or when grown in warm regions or seasons.
- A fine, firm, seedbed will reduce the risk of damage from both slugs and leatherjackets.

Aphid (BYDV) Management

Aphids are the most serious pests of cereal crops in Ireland. Damage occurs in three ways:

1. By transmitting virus disease (BYDV) to and within crops.
2. Direct feeding on tillers can be a problem in some years.
3. By direct feeding in heads

The grain-aphid, *Sitobion avenae*, is the most common aphid vector of BYDV in Ireland. In general, mid-late October drilled wheat is at lower risk of significant BYDV damage than September drilled wheat due to aphid activity patterns.

Recent research in Ireland has confirmed the development of resistance to pyrethroid insecticides (e.g. cypermethrin) in the grain-aphid. Growers need to be aware of this development and consult with their advisors on a suitable integrated pest management strategy.

Aphid Control

- Insecticide seed treatments alone do not give sufficient control of BYDV in early sown crops and should be supplemented with an insecticide foliar spray treatment in early November. All crops sown before mid-October should receive an insecticide seed dressing to reduce the risk of early BYDV infection and will also help prevent hollowing of the seed by slugs.
- Where an insecticide seed treatment hasn't been used apply an aphicide at the 3-5 leaf stage (GS13-15) in crops at risk of BYDV, a follow up aphicide in early November may be required in early drilled crops.
- All aphicides should be applied according to their labels, ensuring good spray coverage.
- Monitor aphid activity after application and where control is poor; consult your advisor and consider applying a non-pyrethroid (Isoclast active) as a follow-up treatment.
- Once feeding aphid numbers reach the threshold of 5 per head in wheat ears dimethoate type aphidicides will give best control.
- Once crops are at milk dough stage (GS75), the yield effect from feeding aphids is negligible.

Leatherjackets

Leatherjackets are the larvae of the Crane Fly (Daddy Long-Legs) and are sporadically a pest of winter wheat. Where numbers are high (possibly as a result of high autumn rainfall), damage can be significant, especially in slowly emerging crops. Leatherjackets reduce yield by reducing plant and tiller numbers. Crows feeding in the evening or early morning can be a sign that leatherjackets are present.

Leatherjacket Control

- Good stubble hygiene will help to reduce the number of leatherjackets.
- Monitor cereals (in high risk fields) for leatherjacket damage at early crop emergence.
- Rolling, if possible, will help.

Slugs

Slugs can also be a problem in slowly emerging crops by hollowing out seed and by grazing emerging plants and leaves. Loose seedbeds, previous cropping, crop residues, wet autumns and field history are important considerations.

Slug Control

- Good stubble hygiene will help reduce slug numbers. Removal of trash and stubble cultivation will help reduce the slug populations.
- Monitoring numbers by laying traps is the key to their management. Bait newly sown crops with some muesli or layer mash (not slug pellets due to the risk to wildlife and pets) under a slate. Leave traps overnight and examine early the following morning. If you find more than 4 the next morning, consider treatment options.
- Concentrate on fields or areas known to suffer damage.
- If thresholds are breached and the crop is being damaged more than it is growing, consider slug pellet application.
- Insecticide seed dressing can help to reduce slug feeding on seed.
- Molluscicide slug control products are based on metaldehyde and ferric phosphate.
- The formulation process of the pellet is important where an extended period of control is required.
- Best results with molluscicides are achieved when applied soon after drilling where high slug numbers have been identified.

Key husbandry factors

- Good stubble hygiene will help reduce populations of slugs and leatherjackets.
- Insecticide seed dressings will reduce slug feeding on seed and the risk of early BYDV infection by aphids.
- Early (September-mid Oct) sown crops are more susceptible to yield loss due to BYDV.
- Fine, firm and well consolidated seed beds will reduce the risk of both slug and Leatherjacket damage.

DISEASE CONTROL

Key Facts

- Main diseases include septoria, rusts, eyespot, take-all and fusarium head blight.
- Diseases reduce both yield quantity and quality.
- Fungicide resistance poses a serious threat to the sustainability of disease control.
- Integration of disease control methods including varietal, cultural and fungicides required.

Owing to the wet mild climatic conditions experienced throughout the season yields of Irish winter wheat crops can be dramatically restricted by a range of diseases. All crops are subject to potential infections in their roots, stems, leaves and ears, all of which reduce final grain yield and quality. It is therefore essential to reduce available inoculum at all stages of crop growth. To be effective such strategies must integrate all available measures of control, and should include:

Agronomy: This includes decisions on when, where and how a crop is planted, through to fertilisation or growth regulation. Each decision will impact upon availability of disease inoculum and/or crop vigour, which combined will determine impact of disease.

Variety Choice: The ability to resist or tolerate diseases must be high on the traits assessed prior to planting. Decisions on what to plant should reflect local disease pressures. Only disease free seed should be planted.

Chemical Control: Fungicide application provides a final layer of protection. Decisions on application timing should be made to achieve maximum protection. Similarly, choice of fungicide product to be used should reflect target disease and time of application.

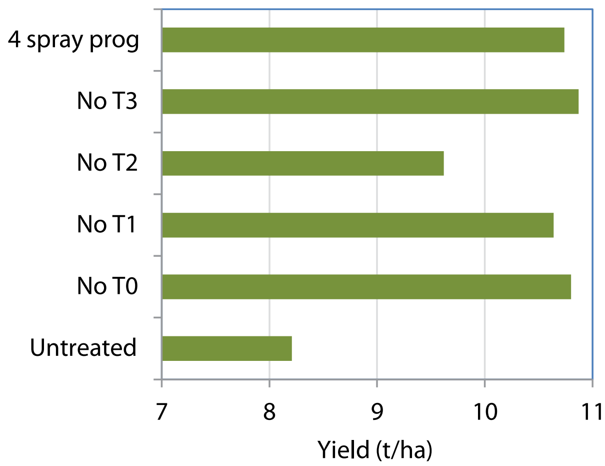
Fungicide Timing

Depending on the target disease and crop growth, fungicides can be applied to the seed, stem, foliage and ear. To maximise their economic return and longevity, fungicide should be applied to achieve maximum efficacy.

Seed treatments: Applied to the seed prior to planting to control seed borne or soil borne disease that can reduce crop establishment or subsequent growth.

Stem/Foliar treatments: Applied from early stem extension through to flowering. Timing of applications must match the growth of the crop, target disease and fungicide characteristics, such as protection or curativity. For foliar based diseases such as septoria, optimal disease control can be achieved through the application of a protectant & curative product to the third last leaf fully emerged and the flag leaf fully emerged.

Ear treatments: Applied at early-mid flowering to protect against Fusarium head blight. Applications at this timing will also top up foliar disease control and choice of fungicides should also reflect this.



Impact of fungicide timings on final yield

Fungicide Resistance

The development of resistance in the major diseases of winter wheat threatens the viability of production in Ireland. Of most concern is septoria, where resistance can rapidly spread through field populations. Whilst fungicide resistance is unfortunately inevitable, the speed at which it emerges and subsequently spreads is dependent on the manner in which they are used. To minimise emergence and spread growers should:

1. Only apply fungicides in mixtures with additional effective modes of action.
2. Use the lowest dose required to achieve effective disease control.
3. Limit the number of applications of individual mode of action within a programme.

Key husbandry factors

- Varietal resistance and ensuring disease free seed essential to reduce risk of disease associated yield loss.
- Delay drilling as late as possible to reduce initial disease infections and subsequent carryover of inoculum.
- Maximise fungicide efficacy through the use of correct timings.
- Mixing fungicides with different modes of action, including multi-sites are essential to maintain disease control and as a fungicide anti-resistance strategy.

MAJOR DISEASES

Septoria Tritici Blotch - Septoria

(Zymoseptoria tritici)

Septoria is the most important disease of wheat in Ireland. By reducing leaf area available for photosynthesis septoria can significantly reduce yields. Thriving in mild wet conditions septoria is prevalent throughout the growing season; however it is only when on the upper leaves that it impacts yield. Control is currently reliant on the application of fungicides to the upper canopy.

Yellow Rust / Brown Rust

(Puccina striiformis f.sp. tritici / P. triticina)

Whilst currently not a major threat to Irish wheat crops, yellow and brown rust have the potential to cause significant yield reductions in winter wheat crops if left untreated. Both reduce the leaf area available for photosynthesis. Control is achieved through correct varietal selection and fungicide intervention.

Fusarium Head Blight - FHB

(Fusarium & Microdochium spp.)

Whilst inoculum of FHB can be found throughout the season it is during flowering that it causes most destruction. By infecting the ear or head of wheat FHB can reduce both the grain yield and quality. Furthermore with the Fusarium spp. also producing a range of mycotoxins can affect subsequent use, whether seed or feed. Control is best achieved through variety choice and correct fungicide application, early-mid flowering.

Common Eyespot

(Oculimacula yallundae & O. acuformis)

Eyespot is a fungal disease which takes the form of eye shaped lesions at the base of the stem. It is most commonly identified by bleach heads scattered throughout the crop during grain filling. In severe infections the disease will reduce the strength of the lower stem, resulting in lodging and associated yield and quality losses. Control is achieved through rotation, varietal selection and application of fungicides at early stem extension.

Take-all

(Gaeumannomyces graminis var. tritici & var. avenae)

Take-all is a root based disease that can cause significant reduction in yield, specifically in 2nd and 3rd wheats. The disease is often observed later in the season as stunted or bleached patches, resulting from restriction of water and nutrient supply to the plants. Rotation with a non-cereal crop is the primary means of control. Seed treatments can reduce the impact of disease, although the impact of the disease will be dependent on the climatic conditions post planting.

Powdery Mildew

(Blumeria graminis f. sp. tritici)

Powdery mildew is often now regarded as a minor disease of winter wheat. However under where the disease does take hold all above grown growth can be infected, leading to significant yield loss. Control is achieved through varietal selection but also crop agronomy, such as crop density and fertilisation. When the disease occurs application of mildewicide fungicides are required.

LODGING CONTROL

Key Facts

- Lodging can significantly impact grain yield and quality.
- Variety choice, N application rate and timing, seed rate and PGR use can all reduce the lodging risk of wheat crops.

Lodging

Lodging is the displacement of a crop from its vertical position. It occurs when the force exerted by the wind on the aerial part of the plant exceeds the strength of the stem base or root anchorage.

The impact of lodging can be significant. Crops that lodge early in the grain filling period can incur large yield losses, due to a reduction in radiation use efficiency and reduced grain fill. Furthermore, lodged crops can incur higher rates of bird damage, and increased losses due to difficult combining conditions.

Additional impacts include increased issues with grain drying, reduced hectolitre weight and grain quality, and a greater risk of mycotoxin production.

Factors affecting lodging

Crops with taller shoots and larger or heavier heads exert a greater force on the base of the plant for any given wind speed.

Narrower stems, thin stem walls and the presence of stem based disease reduce the strength of the lower internodes.

Anchorage is reduced where the structural crown roots are shallow or have a narrow spread (the structural crown roots are the semi-rigid roots that make up the first 2-5cm of the roots), where the soil is weak and wet due to recent rain.

Avoiding lodging

Wheat varieties included in recommended lists are rated for their resistance to lodging. Selecting a variety with strong lodging resistance is an important consideration in fields with a high lodging risk.

High soil fertility and excessive early application of nitrogen can significantly increase lodging risk, as unnecessarily high or early applications rates result in excessive vegetative growth, leading to weaker stem bases and taller shoots. Application of high rates of N prior to GS31 and high residual nitrogen can reduce lodging resistance by 1.5 points on the 0-9 scale, thereby increasing lodging risk.

Early sowing has a similar effect as increased fertility, with denser canopies resulting in weaker stems and taller shoots. Bringing drilling date forward by 2 weeks can reduce the lodging resistance by 1 point.

Plant number can significantly affect root anchorage by altering the spread of the crown roots. An increase in plant number of 50 plants per m^2, can alter the lodging resistance by 2 points.

A loosely compacted soil surface in the spring due to, for example, frost heave can significantly reduce root anchorage. Reconsolidating with a roller prior to stem extension can increase lodging resistance by one.

Plant growth regulators (PGRs) can be used to reduce the risk of crop lodging. However, if all of the previous decisions such as variety choice, seed rate, sowing date and crop nutrition are wrong PGRs will not necessarily be able to eliminate lodging completely. These products primarily reduce lodging risk through shortening the height of the plant, and therefore reducing the force exerted lower down the plant.

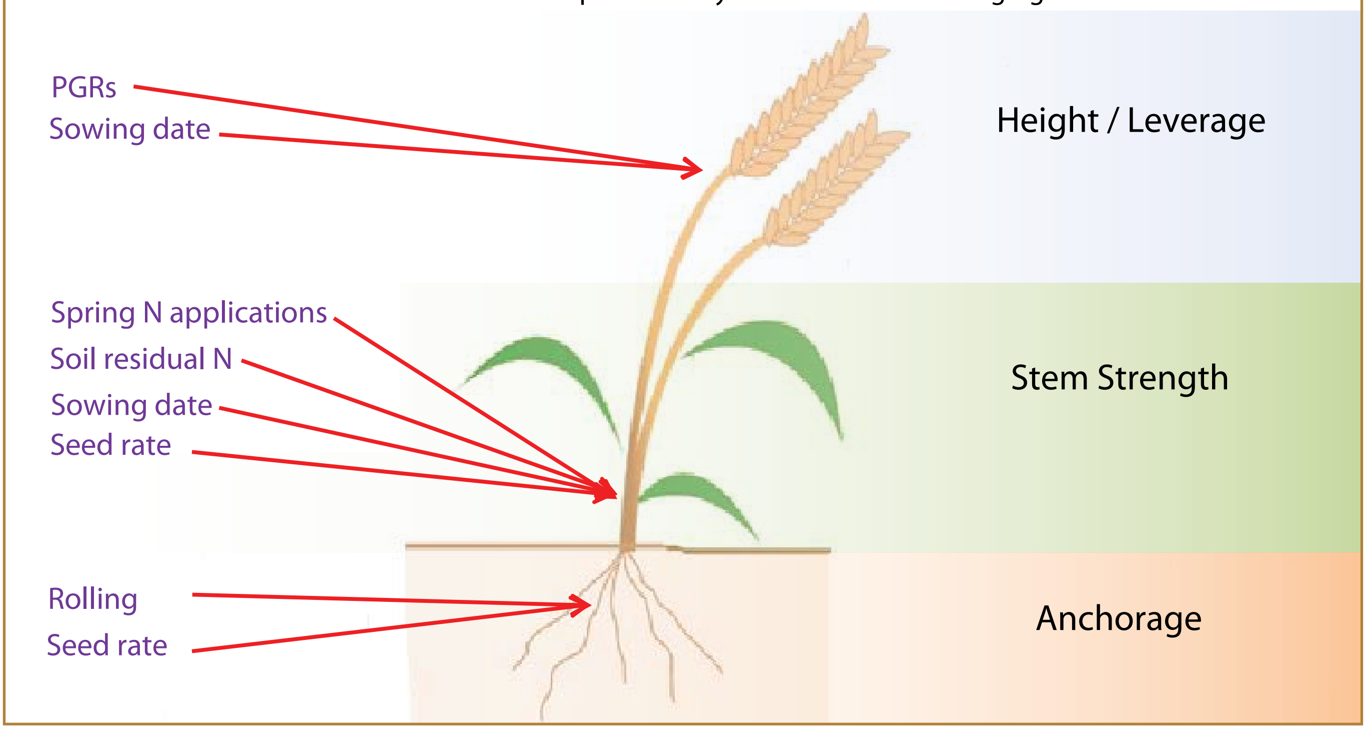
There are broadly two types of PGR that are applied at separate stages of wheat growth. The first is applied around the beginning of stem extension and reduces the length of the stem by inhibiting cell elongation. The second type are generally applied prior to GS39, and inhibit cell division in the upper part of the stem, reducing its length. A single application of PGR at early stem extension reduces lodging risk by about 0.5-1.0, and the application of an additional product at late stem extension can double this.

While PGRs are commonly used on Irish wheat crops, careful consideration of the market requirements for the grain or straw produced is needed when selecting a product to use.

Key husbandry factors

- To minimise lodging risk, limit excessive canopy growth.
- Lodging risk should be considered when selecting sowing date and N application rates.
- Variety selection and PGR use can significantly reduce lodging risk.

Sites of action for crop husbandry factors that affect lodging



GRAIN QUALITY

Key Facts

- Wheat grown in Ireland and Northern Ireland is used as animal feed and is only occasionally used for flour-milling.
- Quality of wheat being traded for animal feed is indicated by specific weight.
- Specific weight is influenced by many factors.

Grain quality in Ireland

The vast majority of wheat grown in Ireland and Northern Ireland is used as animal feed, while wheat used in Irish flour-milling is imported.

Wheat grain comprises mainly starch, which is an energy source in animal feed, with some protein. While the protein content has value in the feed and can allow for reductions in other high-protein components, wheat grain is primarily included in the ration as a source of energy.

Starch content is not routinely measured during purchase of wheat for use in animal feed rations. Specific weight (aka hectolitre weight or bushel weight) is the main characteristic used to determine if a crop is acceptable and to adjust the price.

Example of quality criteria used for purchase of wheat as animal feed	
Minimum specific weight	72 kg/hl
Maximum admixture	2%

Specific weight

Specific weight is an indicator of how dense the grain is, i.e. it is weight related to volume and is measured in units of kilograms per hectolitre (100 litres). It is affected by many factors, including the shape of the individual grains, how they fit together, their packing, and the density of each individual grain.

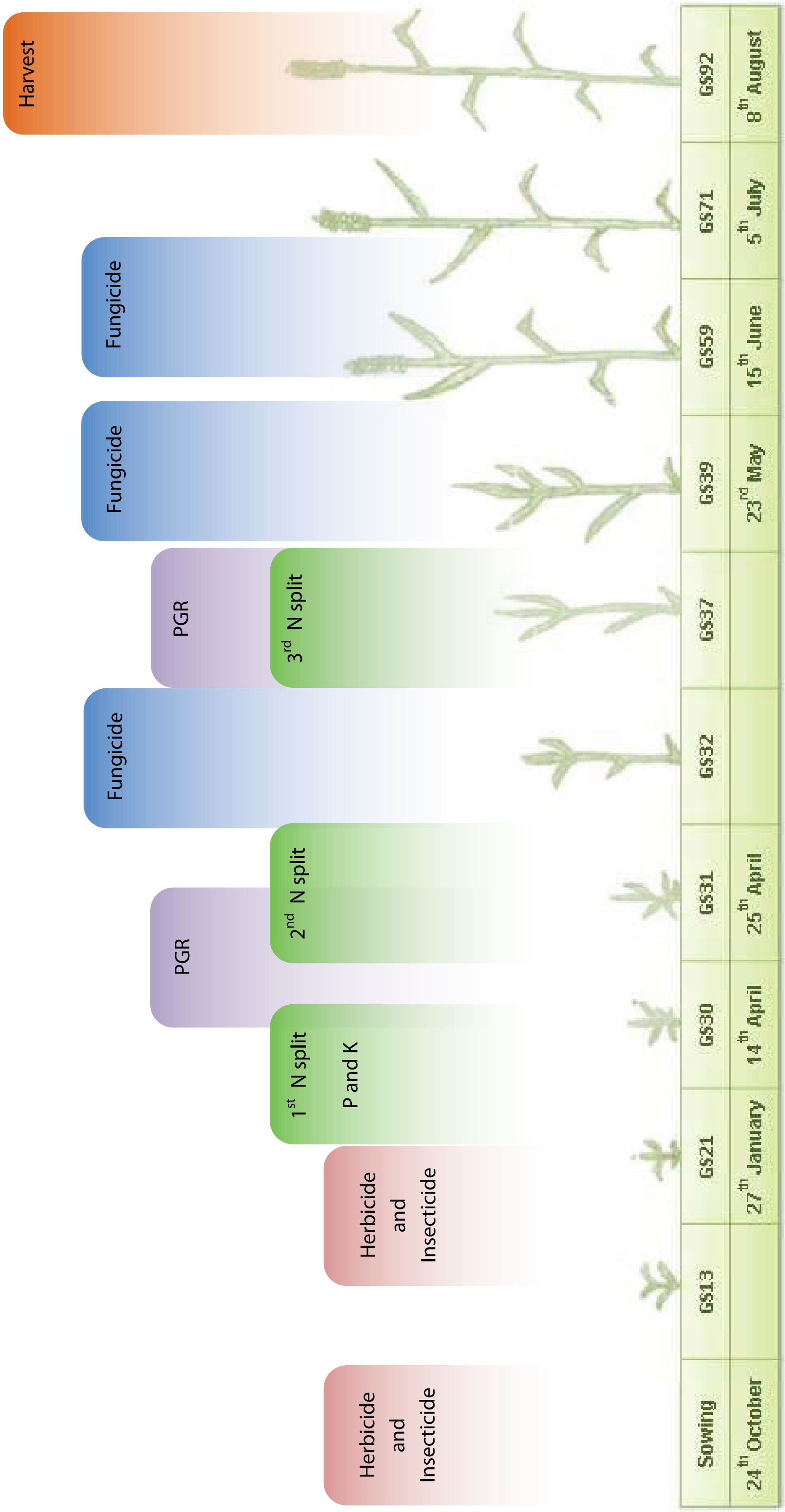
Growing conditions, crop management and variety choice, will have some effect on specific weight. During grain filling, the amount of starch present in the grain will be reduced if photosynthesis by the crop is inhibited. As well as lighter grains, the density of individual grains will be reduced with a possible knock-on reduction in specific weight of the whole grain lot.

Milling wheat

Wheat grain used for flour-milling requires a high protein content, with many consumers specifying a minimum protein content of 13%. Achieving this minimum is challenging in Irish growing conditions due to weather conditions favouring a long grain filling phase, which results in high starch accumulation in the grain and a dilution of the grain protein content.

Other indices of grain quality in flour milling wheat include Hagberg falling number, which measures the amylase activity in the grain.

WINTER WHEAT CROP MANAGEMENT SEASON



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