DE SANGOSSE
by DSG

PHOSPHATE STEWARDSHIP GUIDE

Maximising Crop Performance & Protecting Water



The challenge isn't P supply – it's P availability

Protect it. Place it. Unlock it.

Developed in association with Dr. Christina Baxter of ADAS
Supporting Catchment Sensitive Farming

ADAS

WHY PHOSPHORUS ACCESS MATTERS

Crop performance. Efficiency. Water protection.

Phosphorus (P) is essential for crop growth. It drives root development, establishment, energy transfer (ATP), and yield potential.

However, despite its importance, P is often an elusive nutrient for crops to capture. Plants absorb P as water-soluble orthophosphates.

In many agricultural soils, P is present in sufficient quantities – but not in plant-accessible forms.

IT'S NOT HOW MUCH YOU APPLY
– IT'S WHAT THE CROP CAN ACCESS

What this looks like

- **Poor establishment**
- **Stunted growth**
- **Purpling of older leaves**
- **Poor resource uptake**

"P availability is key-
a high proportion of crops fail to take up sufficient levels to reach their yield potential."

Dr. Christina Baxter
Senior Research Scientist, ADAS

THIS GUIDE EXPLAINS

- Why P uptake efficiency is low
- How poor availability limits crop growth
- How to improve efficiency and reduce environmental risk

ACCESSIBILITY – NOT APPLICATION – DRIVES PERFORMANCE

THE HIDDEN CHALLENGE

Is your phosphate fertiliser actually working?

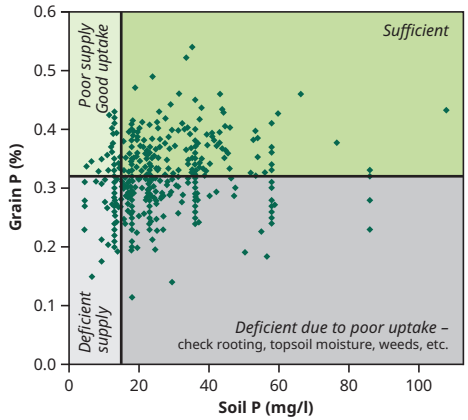
Most UK soils already contain sufficient P to support crop growth.

However, a large proportion of that P is not in plant-accessible forms.

Evidence from the field

Data from the Yield Enhancement Network (YEN) shows:

- Over **60% of cereal crops fall below the critical grain P concentration (0.32%)**
- This suggests crop performance is being limited by **poor uptake – not lack of supply**



Why this happens

- Up to **90% of phosphate fertiliser applications can become locked up within days**
- Up to **60% may never reach the crop**
- Around **70% of soils strongly bind P**
- Only **a small fraction remains in the soil solution where plants can access it**

WHAT THIS MEANS IN PRACTICE

- Soil indices do not fully indicate P availability
- Fertiliser may be applied at the correct rate but is quickly locked up
- Crops are unable to access sufficient P **when they need it most**

THE CHALLENGE IS NOT SUPPLY – IT IS POOR CAPTURE OF P BY THE CROP

LIMITATION 1: ACCESS

Phosphorus doesn't move – roots must find it

PHOSPHORUS HAS A VERY SMALL DIFFUSION DISTANCE

What this means

- P remains where it is placed
- It does not move in the soil water like nitrates
- Roots must physically grow into contact with it

This creates a major limitation early in the season:

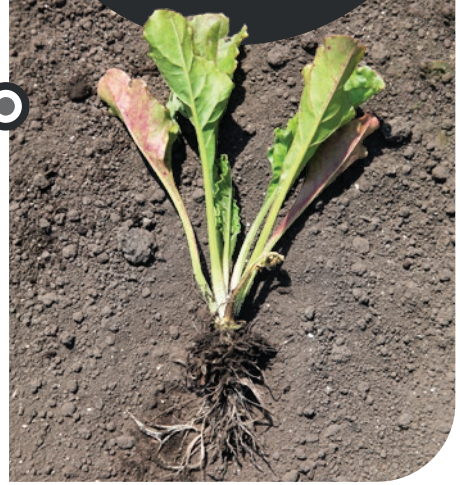
- Root systems are small and undeveloped
- Soil condition can restrict root growth
- Fertiliser applications placed away from the root zone remain unused

FIELD IMPACT

Early growth becomes limited

Establishment slows

Yield potential can be reduced



ROOT ACCESS – NOT TOTAL P SUPPLY – LIMITS UPTAKE

LIMITATION 2: AVAILABILITY

Phosphorus does not remain freely available

Once applied, phosphorus rapidly reacts with soil minerals, reducing the amount available in the soil.

Fixation resulting from soil pH and mineral interactions

Soil condition	What happens	Impact
Calcareous / high pH Alkaline soils	P binds with **calcium (Ca^{2+})**	**P availability may decline rapidly**
Low pH Acidic soils	P binds with **iron and aluminium (Fe^{3+} and Al^{3+})**	**P availability reduced**
Moderate pH / well managed soils	Less fixation	Greater availability

This creates a major limitation early in the season:

- **pH** → drives chemical binding
- **Moisture** → controls movement and uptake
- **Temperature** → affects root activity and availability
- **Soil texture** → sandy soils can hold less P
- **Organic matter** → supports cycling
- **Biology** → drives release from soil reserves and improves root access

OPTIMUM RANGE
pH 6.5-7.0 provides the best balance for availability

P AVAILABILITY IS DYNAMIC – AND STRONGLY CONTROLLED BY SOIL CHEMISTRY AND CONDITIONS

Both limitations operate together – restricting how much P the crop can access and use. This means total soil P is overridden by what is accessible and available to the crop at any given time.

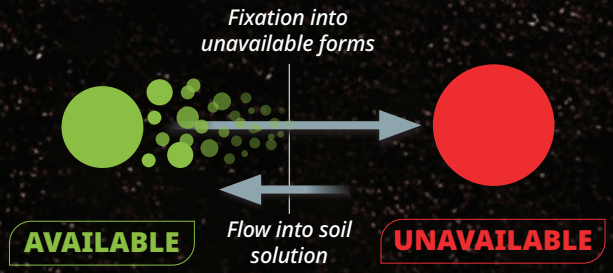
THE SOIL P SYSTEM

Phosphorus is present – but not always available

Phosphorus exists in several forms within the soil, and only one of these is directly available to plants.

What this means

- **Soil solution P →** immediately available to plants
- Plants take up P as orthophosphates ($H_2PO_4^-$ and HPO_4^{2-}) dissolved in the soil solution
- **Fixed P →** bound to soil minerals
- **Organic P →** held in plant residues and soil biology



Key mechanism

Movement between pools is driven by:

- Chemical reactions (adsorption and desorption)
- Biological activity (mineralisation)
- Soil conditions (moisture, temperature, pH)

The role of roots & biology

- Larger root systems increase contact with available P
- Mycorrhizal fungi extend the effective root area
- Increase the volume of soil explored for P
- Soil microbes and root exudates help release bound P
- Biology and root activity directly influence how much phosphorus the crop can capture

ONLY A SMALL FRACTION IS AVAILABLE AT ANY ONE TIME

Total soil P: ~1500-2000 kg/ha

Dissolved in soil water as orthophosphates: ~0.2-4 kg/ha

Most P is present but not available

WHY THIS MATTERS

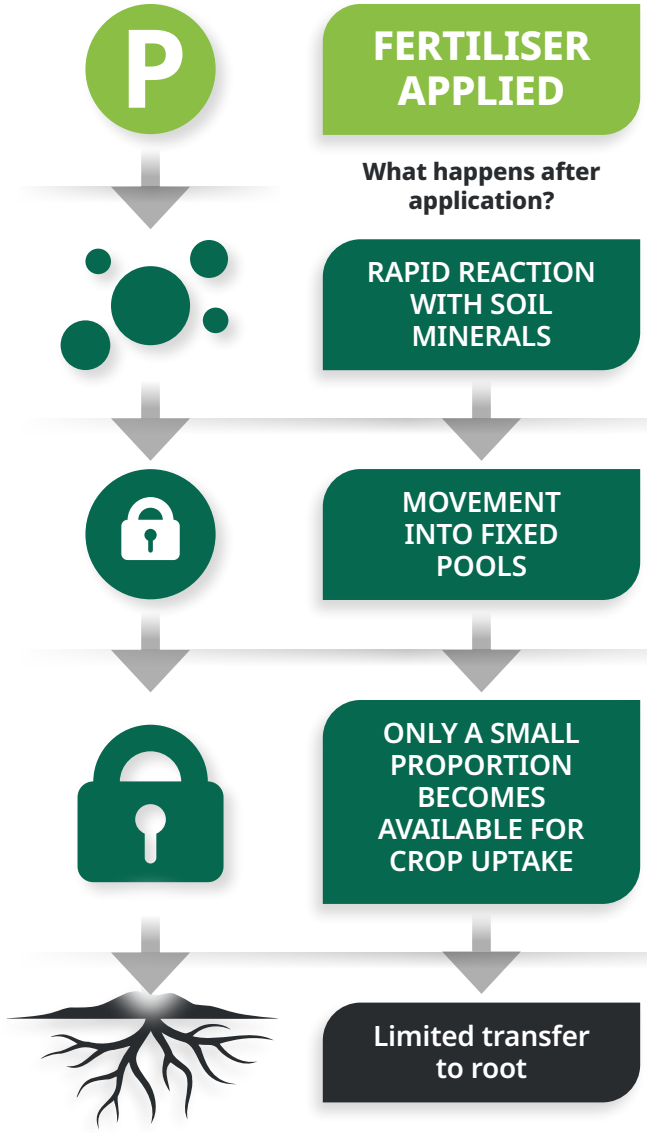
The crop relies entirely on the soil solution for uptake.

Most P must move from fixed or organic forms into this pool.

SUPPLY IS DYNAMIC – DRIVEN BY CHEMISTRY, ROOTS, & BIOLOGY

WHAT YOU APPLY VS WHAT YOU GET

Fertiliser provides supply – not guaranteed uptake



Bagged fertiliser and organic materials add to the soil phosphorus pool – but its availability is quickly controlled by soil processes.

Common sources
MAP / DAP / TSP/ FYM (P applied as P_2O_5 equivalent)

SOIL PROCESSES DETERMINE PERFORMANCE – NOT THE BAG

THE REAL PROBLEM

Why input does not equal output

Phosphorus represents a major investment on farm, applied primarily as phosphate fertiliser. Typically, only 10-20% is taken up by the crop in the year of application, and crop response is often inconsistent.

Typical field

- **Soil P indices used to assess phosphorus status**
- **P applied as P_2O_5 fertiliser**
- **MAP / DAP / TSP →** applied at significant cost to grower

SUPPLY

↓

ACCESS

↓

AVAILABILITY

↓

APPLIED P → **ONLY A SMALL PROPORTION IS AVAILABLE** = **FIXED** → **AVAILABLE**

P INDEX = WHAT'S AVAILABLE NOT THE TOTAL P

WHY THIS HAPPENS

Different parts of the system are often managed independently:

Placement improves access

Increasing rate increases supply

But availability and timing remain limiting

Phosphate fertiliser represents a significant input cost on farm, with applications typically ranging from 20–100 kg P_2O_5/ha depending on crop and soil status.

PHOSPHORUS PERFORMANCE IS A SYSTEM ISSUE – NOT A SINGLE INPUT ISSUE

THE ACTUAL RESULT

- Poor fertiliser efficiency
- **Repeat applications leads to build-up of unused "legacy P" in many soils**
- Continued reliance on inputs

MAKING P WORK

A system approach is required

- **PROTECT** (MAINTAIN AVAILABILITY)
- **PLACE** (IMPROVE ACCESS)
- **UNLOCK** (USE SOIL RESERVES)

PHOSPHORUS MANAGEMENT IS A SYSTEM – NOT A SINGLE INPUT

From earlier sections we established:

- P availability can decline after application
- P movement in soil is extremely limited
- Soil reserves are often present but under utilised

Limitation	Required Action
Fixation	PROTECT IT
Immobility	PLACE IT
Soil reserves	UNLOCK IT

What this means in practice

Each action addresses a different part of the system:

- **Protecting P** → maintains availability after application
- **Placing P** → improves early root access
- **Unlocking P** → increases the use of existing soil reserves

MANAGE AVAILABILITY, ACCESS & RESERVES TO IMPROVE PERFORMANCE

START WITH THE LIMITATION

Identify what is limiting performance

Grain analysis is the first step to identify whether P is limited.

Effective P management then begins with understanding what is limiting crop uptake in each field. Different situations require different approaches.

Common field scenarios

Situation	Priority
Poor early growth	PLACE + PROTECT
Poor fertiliser response	PROTECT
High P, low response	UNLOCK + PROTECT

MATCH THE STRATEGY TO THE LIMITATION – NOT JUST THE APPLICATION RATE

EARLY DEMAND

Demand comes before supply

Early P supply is critical – it sets the foundation for crop performance.

WHAT'S HAPPENING

- Root systems are small and underdeveloped
- **Autumn soil temperatures can be low at drilling**
- **Spring conditions are often dry which leads to phosphate precipitation**
- Biological activity is limited
- **Available P is usually inadequate to support optimal establishment**
- P movement in soil is minimal

THE RESULT

There is a clear mismatch:

- **Crop demand is high**
- **Crop access is restricted**

IMPACT ON THE CROP

- Root development reduced
- Loss of early plant vigour
- Yield potential is reduced

Later applications often cannot fully compensate for limited P supply in early growth.

Many soils contain sufficient P reserves, but improving early availability is key to utilising them effectively

WHAT THIS MEANS IN PRACTICE

Improving early P availability:

- Supports stronger rooting
- Improves crop uniformity and establishment
- Increases yield potential

EARLY P SUPPLY SETS THE FOUNDATION FOR FINAL PERFORMANCE

IMPROVING P PERFORMANCE

A system approach is required

Traditional P programmes focus on supply. However, improving performance requires managing how P behaves in the soil-plant system.

These approaches address the limitations of availability, access and soil reserves identified earlier.

PROTECT

Maintain availability

Reduce fixation

PLACE

Improve root access

Target early growth

UNLOCK

Use soil reserves

Increase availability

SUPPORT

Meet peak demand

Supplement when needed

SUPPLY ALONE DOES NOT GUARANTEE UPTAKE

THE SYSTEM MUST BE MANAGED

These photos demonstrate where a P efficiency strategy has been implemented

(Left untreated, right treated)

NO SINGLE APPROACH SOLVES THE PROBLEM
– SYSTEM PERFORMANCE IMPROVES WHERE THEY ARE COMBINED

Limitation	Solution type
Fixation (availability loss)	Protected P
Poor root access	Placement strategies
Unused soil reserves	Soil nutrient activation
Short-term demand gaps	Foliar / seed / supplementary P

SOIL CONDITION & ROOTING

- Root systems are small and undeveloped
- Soil condition can restrict root growth
- Fertiliser applications placed away from the root zone remain unused

BIOLOGY

- Mycorrhizal fungi form symbiotic relationships with many crop types, increasing the plants access to soil resources
- Improves the crop's ability to access P and other essential nutrients

THE GOAL IS NOT JUST TO SUPPLY P – IT'S TO IMPROVE HOW EFFECTIVELY THE CROP CAN CAPTURE AND USE IT

IMPROVE P EFFICIENCY
REDUCE INPUT REQUIREMENT

- Improve use of existing soil P
- Improve fertiliser use efficiency (e.g. placement)
- Reduce reliance on applied fertiliser
- Maintain performance with lower inputs

PROTECT

PHOSPHATE PROTECTION TECHNOLOGIES

- Reduce fixation by soil minerals
- Maintain P in plant-available form
- Extend the window for crop uptake

Includes: Fertiliser granule coatings, liquid fertiliser additives

→ Supports early availability and ENHANCES FERTILISER USE EFFICIENCY

PLACE

PLACEMENT STRATEGIES

- Position P in the developing root zone
- Increase early root interception
- Improve establishment

Includes: Microgranular starter fertilisers, placed fertiliser at drilling, seed treatments

→ Targeted placement enhances early root access and can reduce overall fertiliser requirement

Note: Improved rooting increases the crop's ability to capture phosphorus

IMPROVING EFFICIENCY REDUCES INPUT REQUIREMENT WHILE MAINTAINING PERFORMANCE

UNLOCK

SOIL NUTRIENT ACTIVATION

Where P reserves exist, improving their utilisation becomes critical.

These approaches aim to:

- Release P from soil-bound forms
- Increase availability from reserves
- Support nutrient cycling
- Reap historic investment made in P fertiliser
- Reduce requirement for P fertiliser

Mechanism

- Work by releasing organic acids
- Similar to natural root exudates
- Help mobilise P from bound forms

→ This mimics natural biological processes in the soil

Includes: Soil nutrient activators, biological stimulants, soil conditioning approaches

→ Particularly relevant in moderate to high index soils

SUPPORT

TARGETED SUPPLEMENTARY NUTRITION

Foliar applied P during the growing season can help:

- Support crop demand at key stages
- Overcome temporary limitations in availability
- Complements soil-based supply

Includes: Foliar P applications, protected P seed treatments, in-season targeted nutrition

→ Used to complement – not replace – soil-based supply

SYSTEM APPROACHES DELIVER BETTER PERFORMANCE

- **Microgranular starter fertilisers** – for targeted early access
- **Protected P fertilisers** – to maintain availability
- **Soil nutrient activators** – to improve use of existing reserves
- **Foliar or seed-applied P** can be used to support demand at key stages.

IMPROVING EFFICIENCY REDUCES INPUT REQUIREMENT WHILE MAINTAINING PERFORMANCE

SOIL RESERVES

Are you making the most of what's already there?

In many UK soils, decades of application have led to substantial phosphorus reserves that are not fully utilised by crops.

LOW UPTAKE EFFICIENCY – NOT LOW SUPPLY

IS OFTEN THE REAL LIMITATION

PHOSPHORUS STATUS & DECISION MAKING

Using P Index to guide management

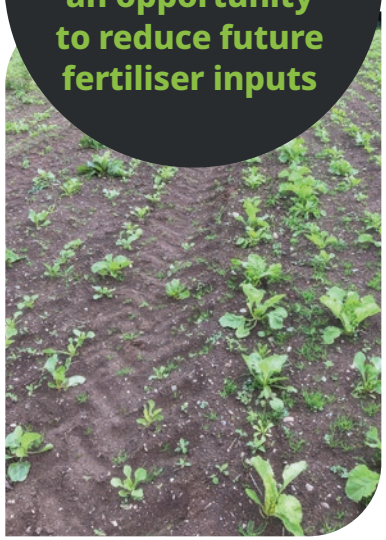
Olsen P is widely used to assess soil phosphorus status in calcareous soils, and the Bray Method is used in acidic soils. The results form the P Index and guide fertiliser decisions.

High soil P does not guarantee high crop uptake

SOIL P RESERVES
CROP UPTAKE

Nutrient	Typical efficiency
Nitrogen	~60%
Phosphorus	10-20%

Improving utilisation of soil reserves creates an opportunity to reduce future fertiliser inputs



P Index = WHAT'S AVAILABLE

NOT TOTAL P

Typical interpretation

Index	P Index (mg/l)	Interpretation
0-1	<15	Low – likely responsive
2	16-25	Target – sufficient supply
3	26-45	High – optimise use
4+	>45	Excess – potential risk

THE REALITY

- Most UK agricultural soils contain significant P reserves
- In many cases, inputs exceed crop removal
- P accumulates as "legacy P"

IMPORTANT DISTINCTION

The P Index indicates **short-term crop availability** – but it does not always reflect **longer-term supply potential**

WHY THIS HAPPENS

A large proportion of soil P is:

- Tightly bound to soil minerals
- Held in organic forms
- Not readily plant available

IN PRACTICE

At Index 2 and above, growers often still see:

- Poor early growth
- Inconsistent fertiliser response
- Continued requirements for inputs

IMPROVING UTILISATION OF SOIL RESERVES REQUIRES THE IMPLEMENTATION OF STRATEGIES TO ENHANCE P EFFICIENCY

PHOSPHATE LOSS & WATER QUALITY

What happens to unused P?

Phosphorus that is not captured by the crop remains in the system.

This presents both lost productivity and increased environmental risk.

Phosphorus is an essential crop nutrient – but in surface waters it becomes a pollutant. When phosphate from agricultural land reaches rivers, streams and lakes, it drives a process called **eutrophication**: excessive algal and plant growth that degrades aquatic ecosystems and threatens water quality.

The Eutrophication Cascade

- **NUTRIENT ENRICHMENT**
  Elevated P level in water
- **ALGAL BLOOMS**
  Rapid phytoplankton & cyanobacteria growth
- **LIGHT AND OXYGEN LOSS**
  Turbidity blocks light; decomposition depletes O_2
- **ECOLOGICAL DAMAGE**
  Loss of aquatic life and biodiversity decline

HOW PHOSPHATE TRAVELS FROM FIELD TO WATER

FERTILISER APPLICATION
Inorganic / Organic

↓

SOIL ACCUMULATION
Surplus builds in topsoil

↓

SURFACE RUN-OFF & EROSION
Rainfall mobilises P

↓

WATERCOURSE ENTRY
Rivers, drains, ditches

PHOSPHATE NOT USED BY THE CROP BECOMES A LOSS RISK

FIELD PRACTICES THAT INCREASE P LOSS RISK

- **High soil phosphorus index** (P Index 3+) – soils with surplus P release more during runoff events
- **Applications to bare or recently cultivated soil** before rainfall
- Fields with **steep slopes or compacted soils –** accelerates surface water flow
- **Spreading within 10m of a watercourse –** increased direct pathway risk
- **Preferential flow pathways**: mole drains, field drains, macropores in clay soils

68%
OF ENGLISH RIVERS FAIL GOOD ECOLOGICAL STATUS
ELEVATED P IS A LEADING CAUSE

TREATMENT, FISHERY LOSSES & AMENITY LOSSES COST HUNDREDS OF MILLIONS ANNUALLY

25-40%
OF P ENTERING WATERCOURSES COMES FROM AGRICULTURE
ELEVATED P IS A LEADING CAUSE

WHAT GOOD PHOSPHATE STEWARDSHIP LOOKS LIKE

DO NOW

- Identify crop P limitation using grain analysis
- Test soils and maintain P Index records
- Target applications only where crop demand genuinely justifies it – avoid blanket maintenance dressings on P Index 2+ fields
- P input still recommended in Index 3 soils for responsive crops such as potatoes
- Observe mandatory buffer zones for storage and spreading
- Follow Farming Rules for Water at all times

PLAN

- Establish or maintain riparian buffer strips (6 m minimum) to intercept runoff
- Grass waterways and cover crops on vulnerable land will reduce erosion and P loss
- Time applications to avoid soil saturation and forecast rainfall events
- Use decision support tools to match rate to actual crop need

MONITOR

- Track field-scale P balances annually
- Where organic manures are used, credit their P content fully against crop nutrient requirements using RB209
- Review drainage infrastructure
- Ensure field drains don't create a direct pathway to surface water – especially in high-risk catchments

APPLYING P BEYOND CROP NEED CREATES LOSS RISK

PRECISION NUTRITION PROTECTS BOTH COST AND WATER

MATCHING STRATEGY TO SOIL STATUS

Different soils require different approaches

MANAGEMENT SHOULD CHANGE WITH SOIL STATUS
NOT JUST APPLICATION RATES

Soil Index	Situation	Priority	Strategy
LOW P (Index 0-1)	Supply is limited	• Build soil P • Improve early access	**PLACE + PROTECT**
TARGET P (Index 2)	Supply is adequate – uptake is limiting	• Maintain index • Improve early availability • Reduce dependence on further P	**PLACE + PROTECT + UNLOCK**
HIGH P (Index 3)	Available P sufficient for crop – utilisation may still be limiting	• Improve use of existing P • Reduce dependence on new inputs • Reduce indices over time	**UNLOCK + PROTECT**

P Index indicates short-term availability – not total soil reserves

WHAT THIS MEANS

- High-yielding crops remove significant P
- Replacement maintains soil fertility
- But **uptake efficiency determines performance**

DEMAND, REMOVAL & REQUIREMENT

Phosphorus demand is significant – and varies by crop

Crop requirement for phosphorus is driven by removal in harvested produce.

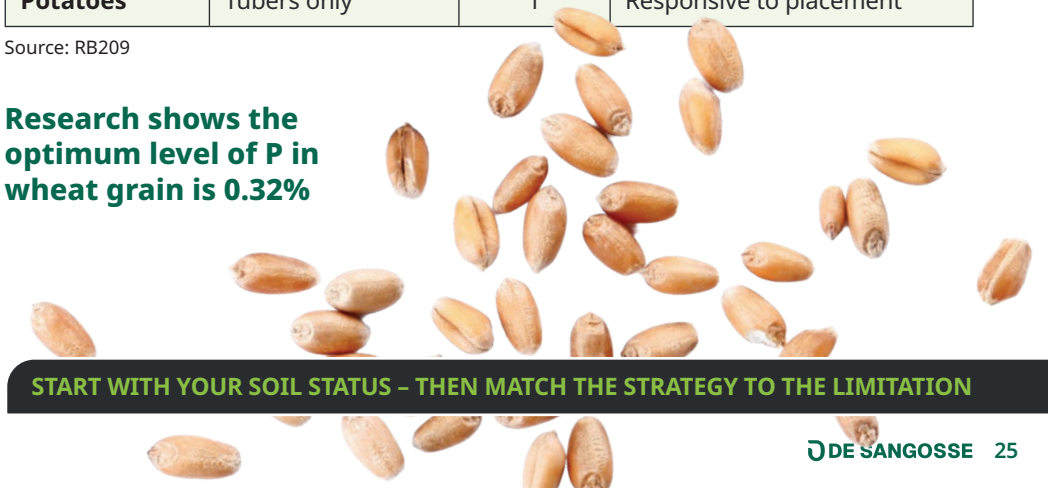
Offtake = Yield x P removal

Typical crop removals (P_2O_5 kg/t)

Crop material		Removal	Commentary
Wheat	Grain only	6.5	Moderate demand
	Grain and straw	7.0	
Barley	Grain only	8.0	Slightly higher than wheat
	Grain and straw	8.5	
Field beans	Seed and straw	11	High demand crop
Oilseed rape	Seed only	14	High demand crop
	Seed and straw	15	
Maize	Silage	1.4	Responsive to placement
Potatoes	Tubers only	1	Responsive to placement

Source: RB209

Research shows the optimum level of P in wheat grain is 0.32%



START WITH YOUR SOIL STATUS – THEN MATCH THE STRATEGY TO THE LIMITATION

DEFICIENCY IS OFTEN AN AVAILABILITY & ACCESS ISSUE – NOT A SUPPLY ISSUE

Recognising P Limitation

COMMON SYMPTOMS:

- Slow establishment
- Reduced tillering
- Stunted growth
- Purpling of leaves

KEY INSIGHT

These symptoms do not always indicate low soil P. They are often caused by:

- Limited availability in the soil
- Poor root access
- Unfavourable soil conditions

DEFICIENCY IS OFTEN SEEN AS PURPLING IN THE OLDER LEAVES AS P REMOBILISES TO NEWER GROWTH

PHOSPHATE STEWARDSHIP

Getting phosphorus management right

IT'S NOT HOW MUCH YOU APPLY

IT'S HOW MUCH THE CROP CAN CAPTURE & USE

- Supply alone is not enough
- Availability and access must be managed
- Most soils already contain significant P reserves
- Efficiency drives both performance and sustainability

PROTECT
Maintain availability

UNLOCK
Use soil reserves

PLACE
Improve access

REDUCE
Lower input requirement through improved efficiency

IMPROVING PHOSPHATE USE EFFICIENCY

DELIVERS BETTER CROP PERFORMANCE AND PROTECTS WATER QUALITY

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Improving phosphate efficiency for better crop performance and water protection

Developed in association with Dr. Christina Baxter of ADAS
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