

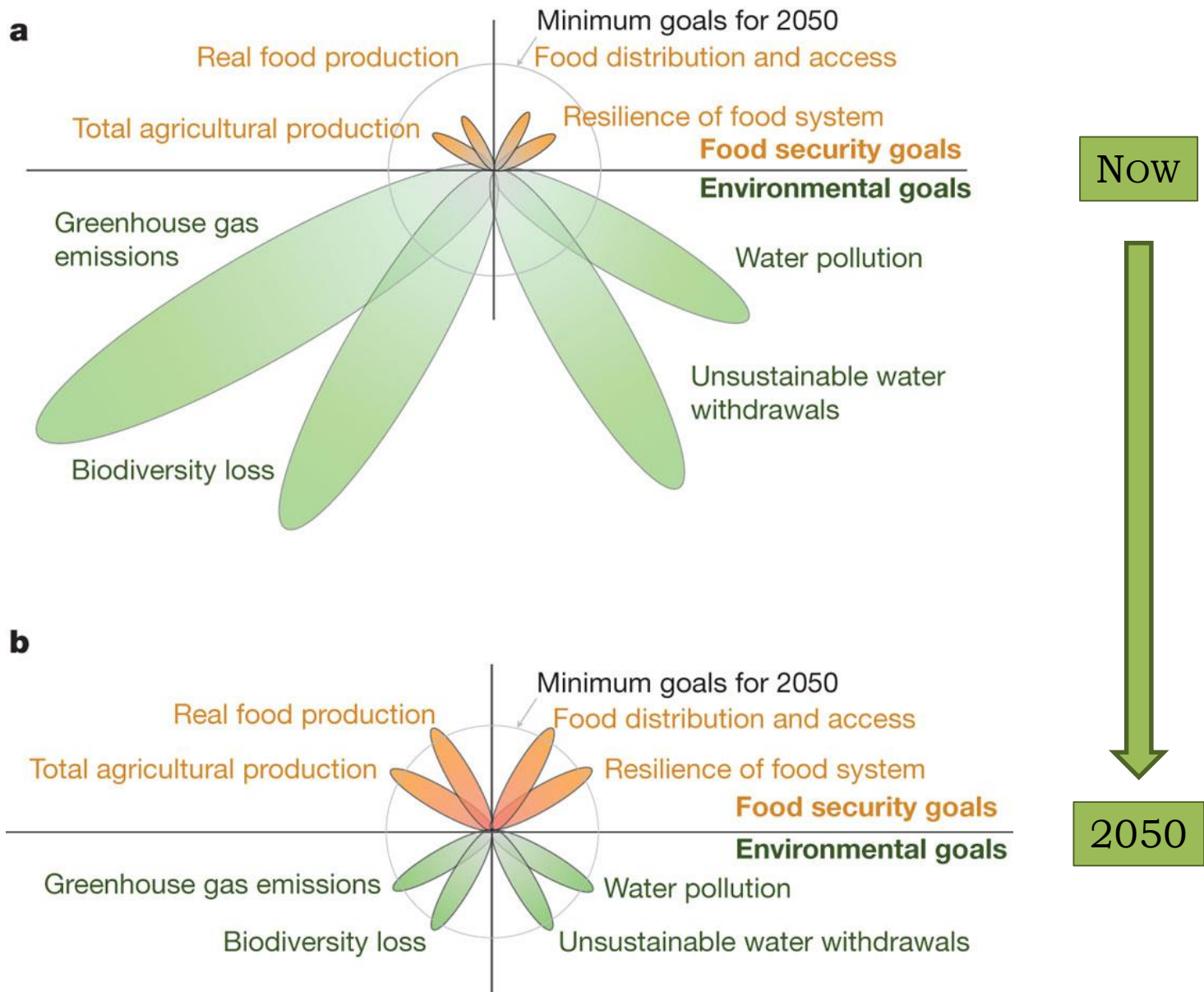
BREEDING FORAGES TO COPE WITH
ENVIRONMENTAL CHALLENGES IN THE LIGHT OF
CLIMATE CHANGE AND LIMITED RESOURCES

Á. HELGADÓTTIR, L. ØSTREM, R.P. COLLINS, M. HUMPHREYS, A.
MARSHALL, B. JULIER, F. GASTAL, P. BARRE, G. LOUARN

TWO MAJOR
DRIVERS
FOR THE FUTURE

PROJECTED CLIMATE CHANGE

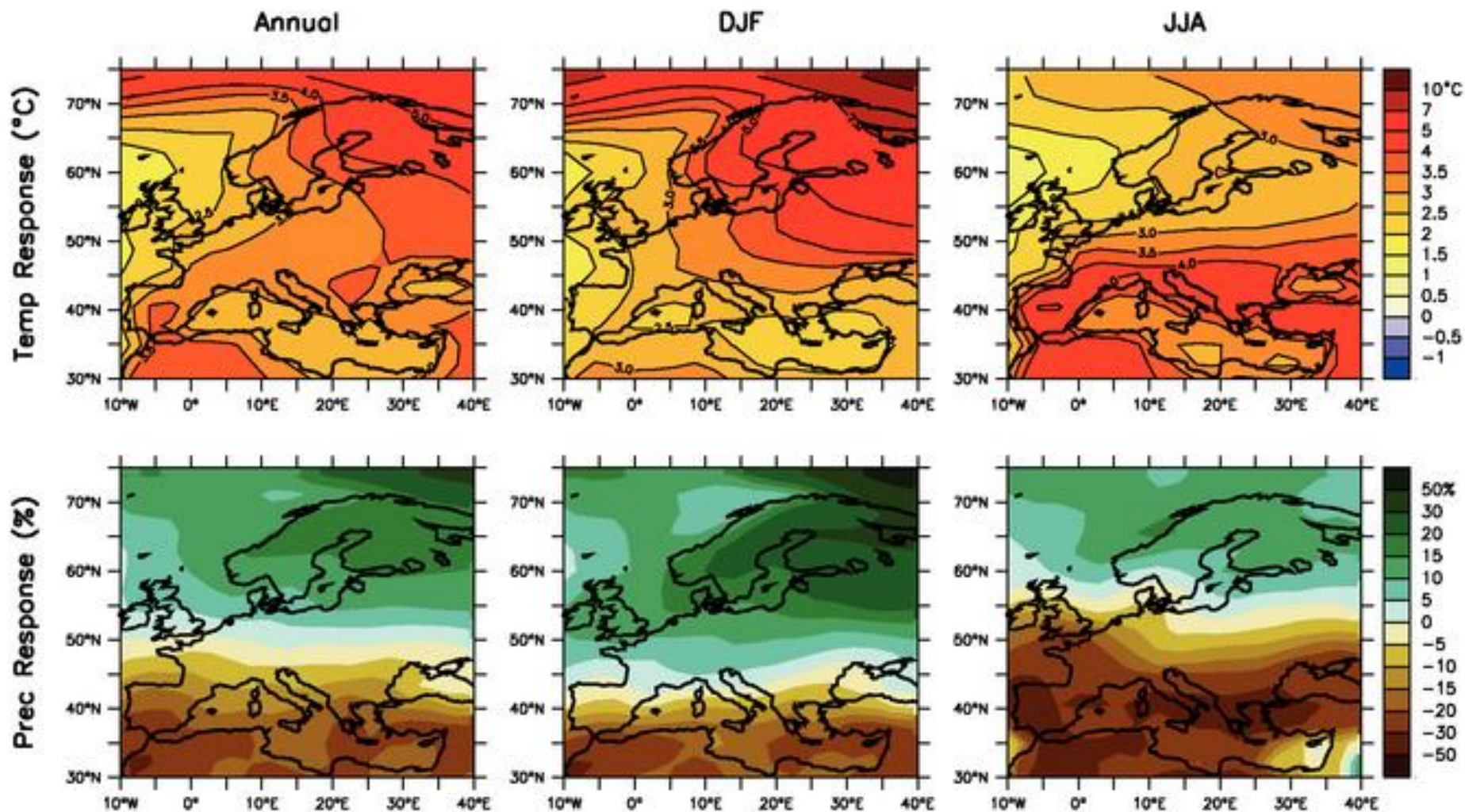
INCREASED PRESSURE TO IMPROVE EFFICIENCY
OF WATER AND NUTRIENT USE



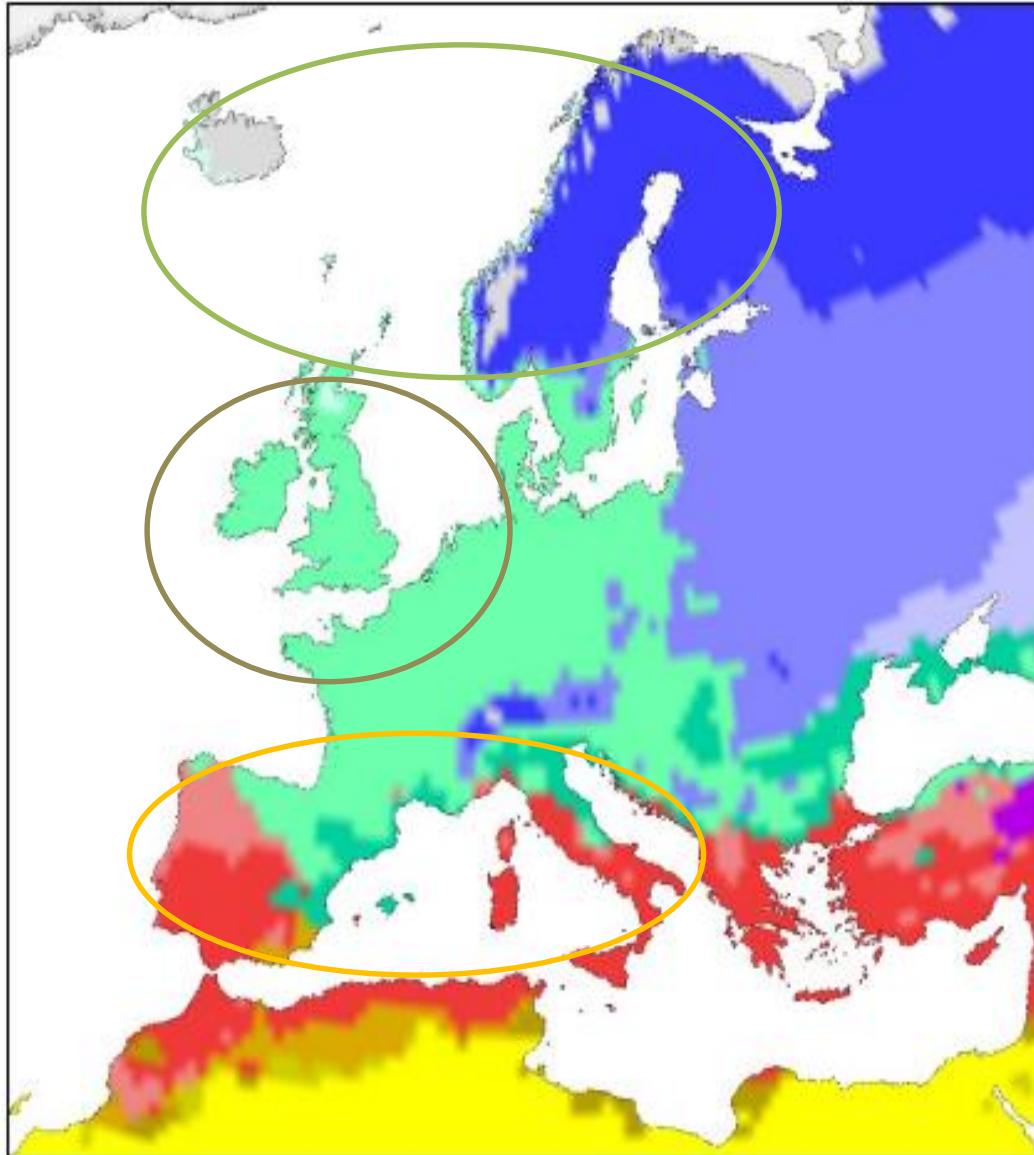
PROJECTED
CLIMATE CHANGE
IN EUROPE



PROJECTED CLIMATE CHANGE IN EUROPE 1990-2090 SCENARIO A1B



KÖPPEN CLIMATE REGIONS 1961-1990



Warm climate

■ Dry

■ Very dry

Mild climate

■ Dry summer

■ Rain all year

Cool climate

■ Dry summer

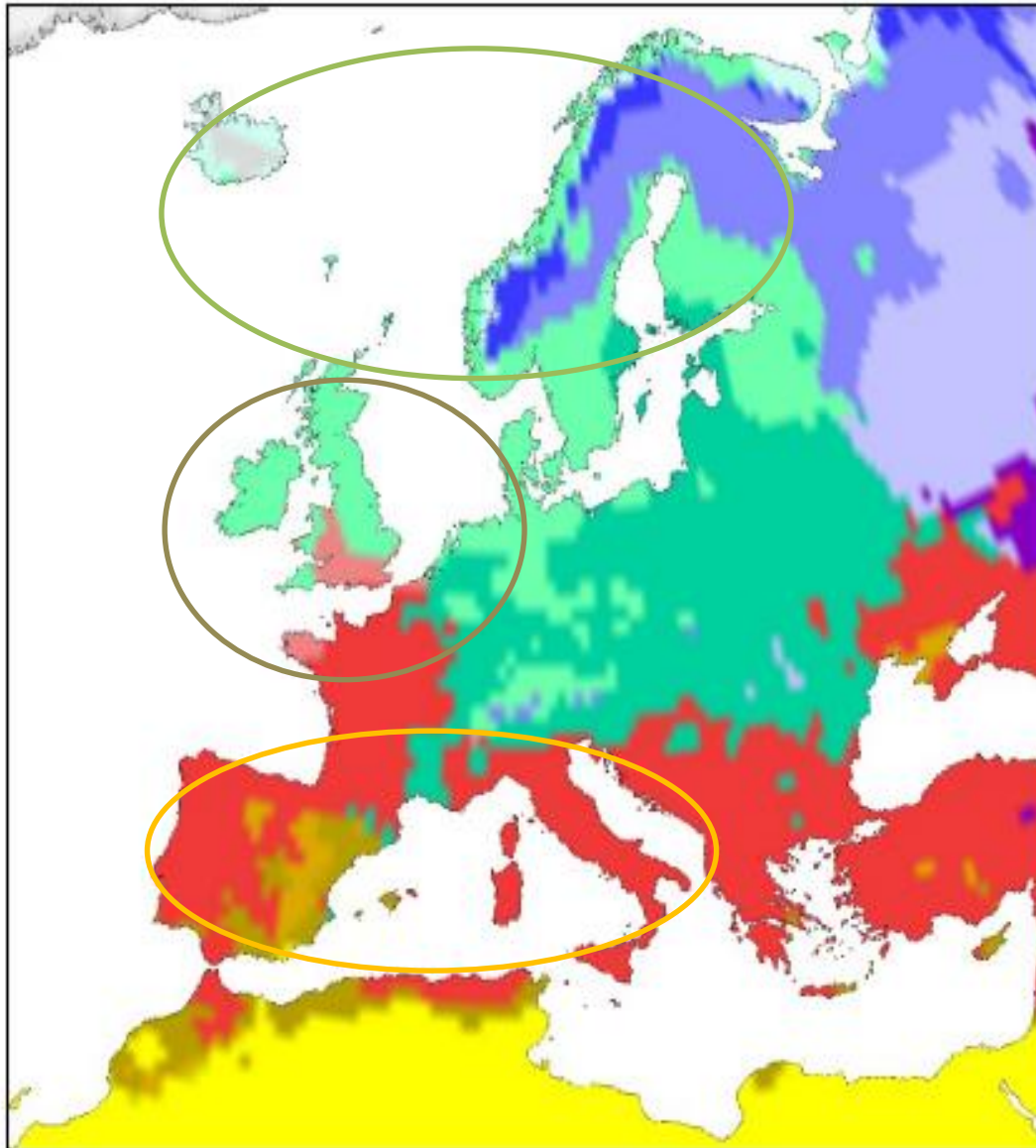
■ Rain all year

Polar climate

■ Tundra

■ Ice/snow

KÖPPEN CLIMATE REGIONS 2080 (A2)



Warm climate

■ Dry

■ Very dry

Mild climate

■ Dry summer

■ Rain all year

Cool climate

■ Dry summer

■ Rain all year

Polar climate

■ Tundra

■ Ice/snow

IMPORTANT TO IMPROVE LAND AND NUTRIENT USE EFFICIENCY

- OBTAIN MORE FEEDING UNITS PER LAND UNIT
 - IMPROVE THE QUALITY THROUGH BREEDING
 - OPTIMISE D-VALUES THROUGH MANAGEMENT STRATEGIES
- REDUCE THE RELIANCE ON ARTIFICIAL FERTILISERS
 - INTRODUCE N-FIXING SPECIES INTO FORAGE MIXTURES

THE ROLE OF PLANT BREEDING FOR ADAPTING
FORAGE PRODUCTION SYSTEMS TO
CHANGING CLIMATE AND LIMITED RESOURCES

DEVELOP NEW VARIETIES OF CURRENTLY GROWN
SPECIES AND IDENTIFY USEFUL TRAITS

AND/OR

INTRODUCE EXOTIC MATERIAL AND ADAPT IT TO THE NEW
ENVIRONMENT

APPROPRIATE TRAITS



IMPROVE FORAGE QUALITY

MAXIMISE RESOURCE USE EFFICIENCY

FINE-TUNE PLANT DEVELOPMENT PROCESSES

INCREASE RESISTANCE TO BIOTIC AND ABIOTIC STRESSES

THIS PRESENTATION

NORDIC ENVIRONMENT:

TRAITS TO SECURE HIGH YIELDS UNDER CHANGED
OVERWINTERING CONDITIONS

TIMOTHY AND PERENNIAL RYEGRASS

MARITIME, OCEANIC EUROPE:

ROOT SYSTEMS TO IMPROVE NUTRIENT AND WATER USE

FESTULOLIUM AND *TRIFOLIUM* HYBRIDS

TEMPERATE AND SOUTHERN EUROPE:

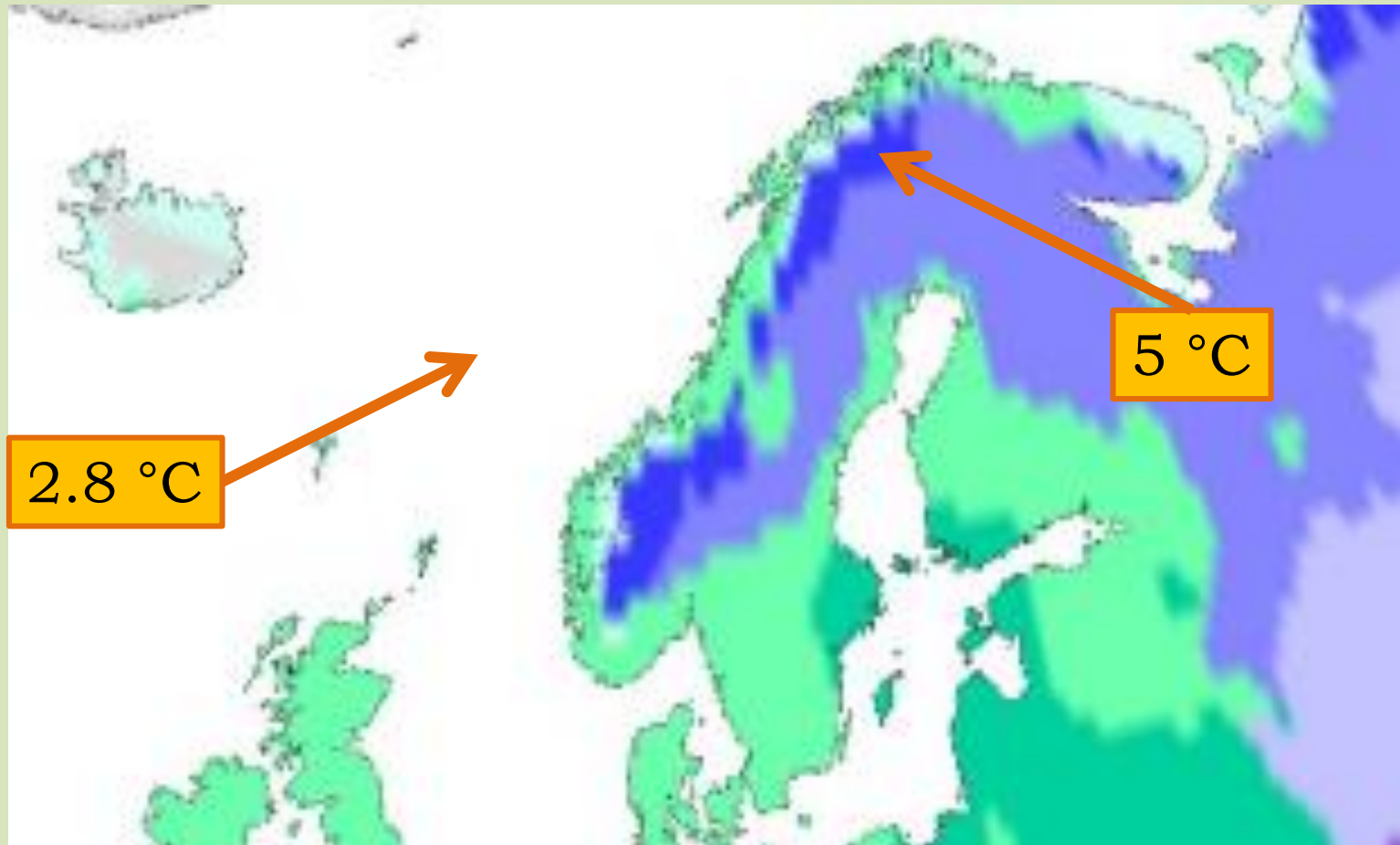
TRAITS TO SURVIVE LONG DROUGHT PERIODS AND QUICK
RECOVERY AFTER AUTUMN RAINS

LUCERNE, COCKSFOOT

THE NORDIC ENVIRONMENT



PROJECTED CHANGES (A1B SCENARIO)



INCREASED PRECIPITATION IN WINTER

POSITIVE IMPLICATIONS



LONGER AND WARMER GROWING SEASON

WARMER AUTUMNS

INCREASED BIOMASS PRODUCTION POTENTIAL

Photo: Magnus Halling

CHALLENGES



OVERWINTERING PROBLEMS

INCREASED DISEASE PRESSURE

Photo: Jónatan Hermannsson



WINTER STRESSES

FROST

WATER LOGGING

LOW LIGHT INTENSITY

WEST

EAST

MILD PERIODS DURING WINTER

LONG-LASTING SNOW COVER

REPEATED FREEZE-THAW CYCLES

LOW TEMPERATURE FUNGI

ICE ENCASEMENT



ADAPTING PERENNIAL GRASSES TO A NEW
CLIMATE AT HIGHER LATITUDES

WE WANT CULTIVARS WITH INCREASED BIOMASS
PRODUCTION, BUT TRADE-OFF BETWEEN
EXTENDED AUTUMN GROWTH AND
WINTER SURVIVAL

HOW IS
GROWTH CESSATION
RELATED TO
LATE AUTUMN GROWTH
PHOTOSYNTHETIC ACTIVITY
WINTER DAMAGE

?

HOW TO SELECT FOR GROWTH CESSATION?

FREEZING TESTS:
CROWN TISSUE / LT_{50}

CHLOROPHYLL FLUORESCENCE
MEASUREMENTS IN THE FIELD

NDVI – MEASURES PHOTOSYNTHETIC
ACTIVITY



TIMOTHY

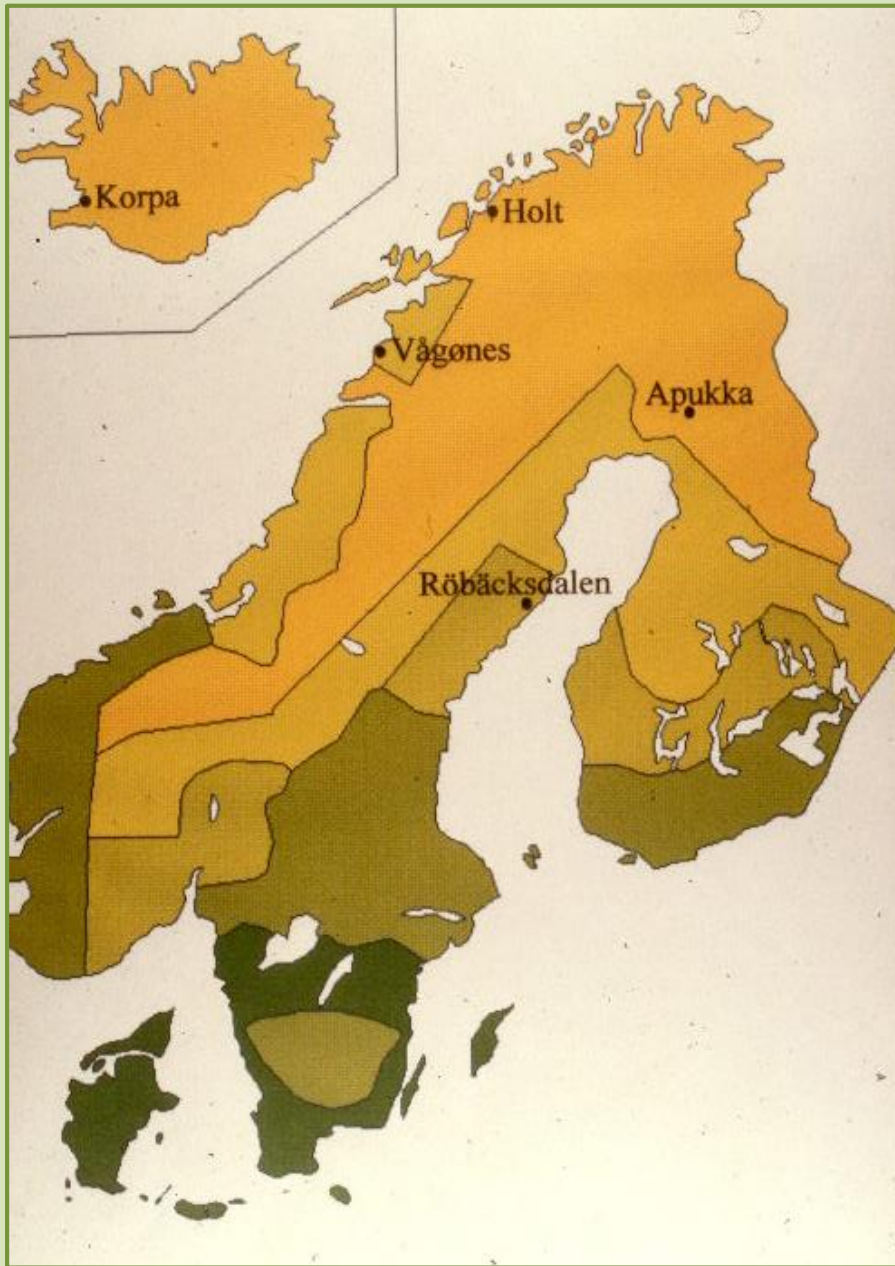


>60°N

RYEGRASS FESTULOLIUM



<60°N

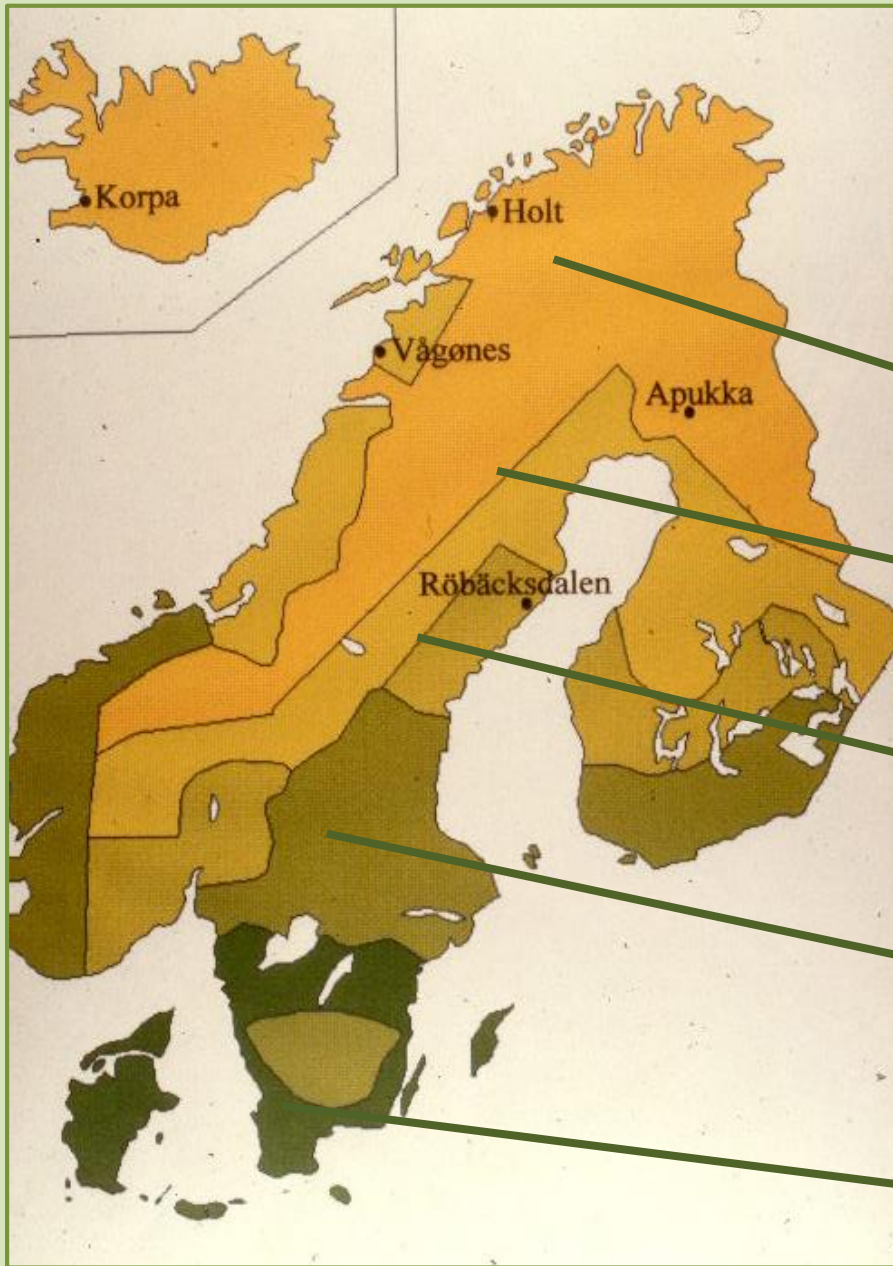


AGROCLIMATIC ZONES FOR TIMOTHY



(FROM HÓLMGEIR BJÖRNSSON, 1993)

YIELD POTENTIAL TONN HA⁻¹



ZONE 5: 4.40

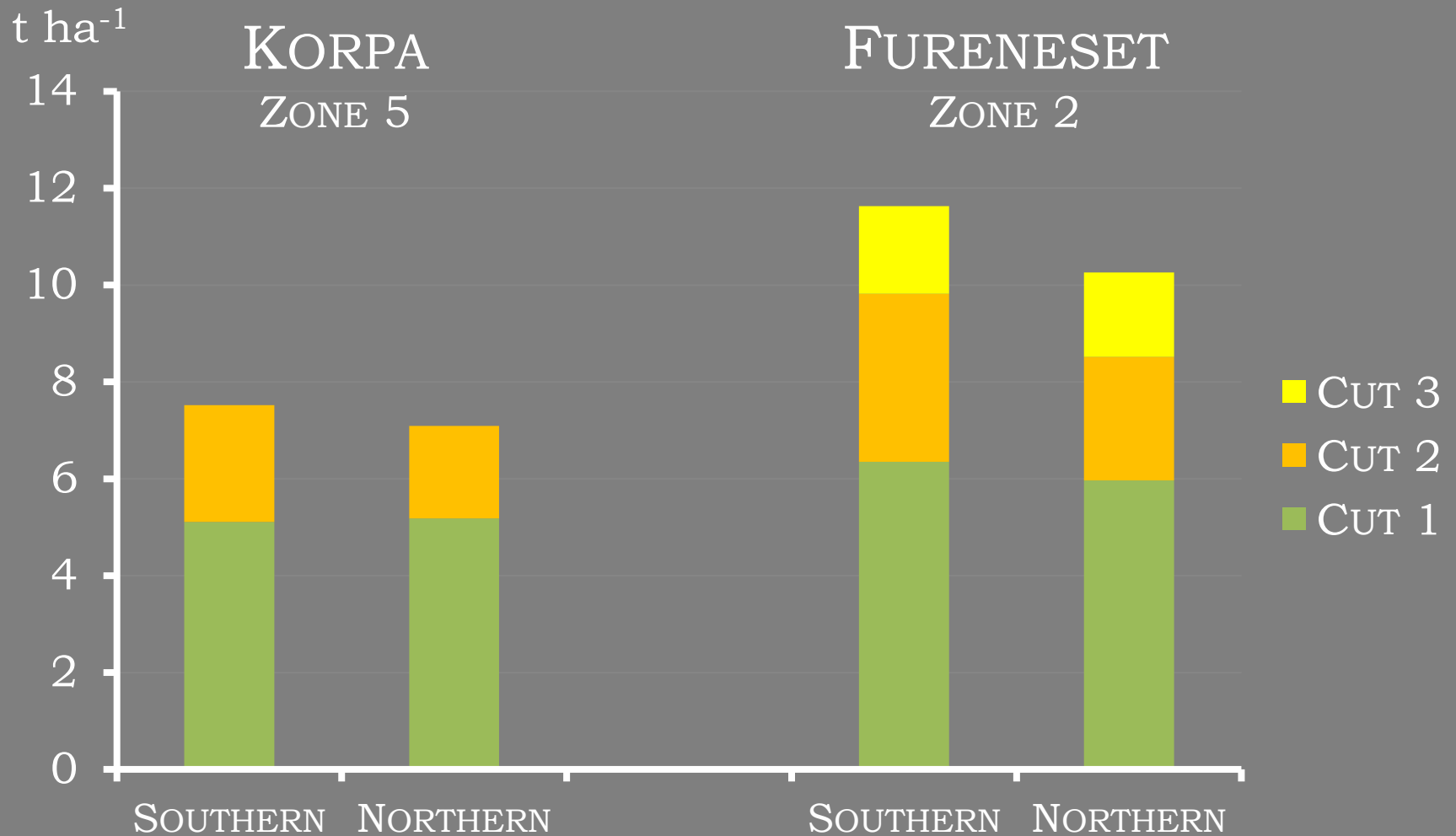
ZONE 4: 6.92

ZONE 3: 8.50

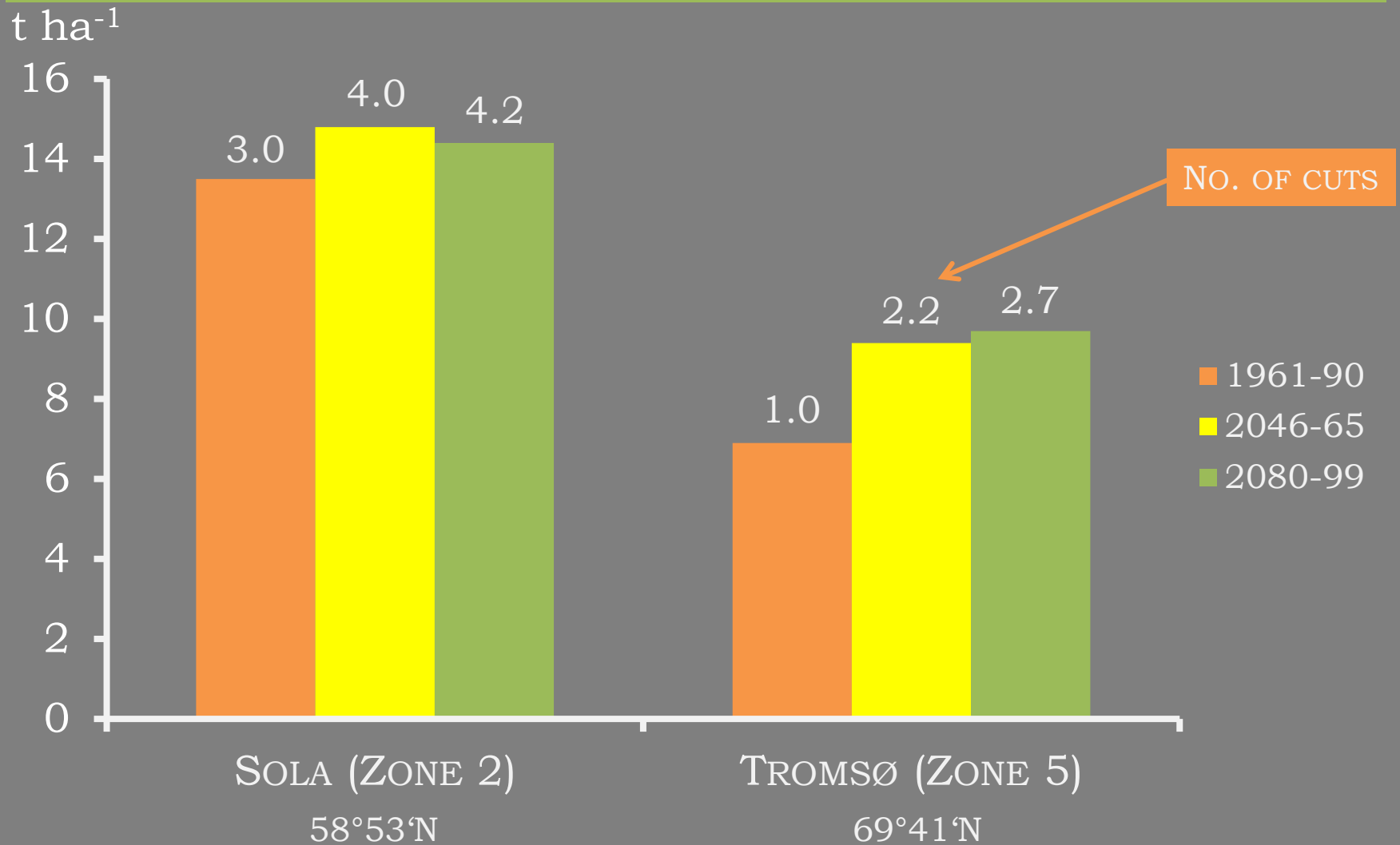
ZONE 2: 9.34

ZONE 1: 9.23

YIELDING ABILITY AND REGROWTH POTENTIAL



MODEL PREDICTIONS FOR THE FUTURE: CLEAR BENEFITS FOR TIMOTHY



WARMER AUTUMNS?

EFFECTS ON HARDENING – LT_{50}

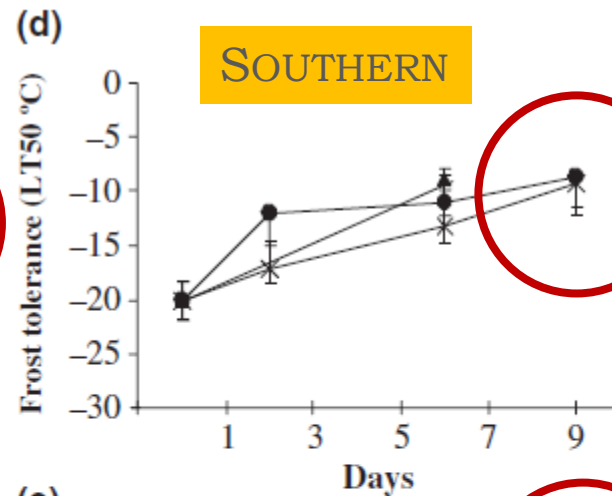
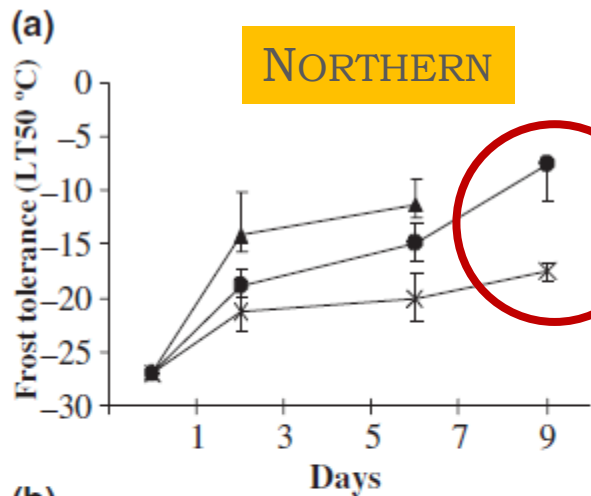
| | PRE-ACCLIMATION TEMPERATURE TREATMENT, °C | | |
|----------|---|-------|-------|
| | 9 | 12 | 15 |
| NORTHERN | -19.3 | -14.8 | -14.1 |
| SOUTHERN | -14.7 | -14.7 | -12.2 |

(DALMANNSDÓTTIR ET AL. 2015)

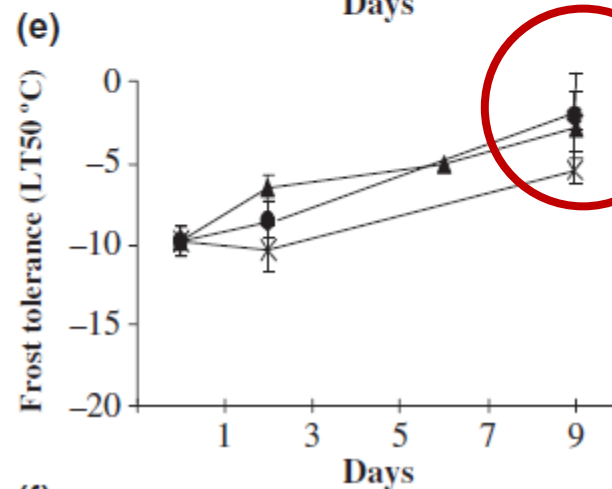
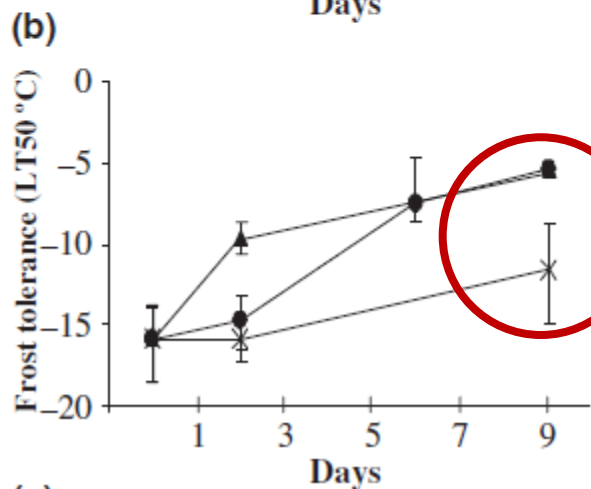
WARM SPELLS DURING WINTER?

EFFECTS OF DEHARDENING – LT_{50}
(X) 3°C (●) 9°C (Δ) 15°C

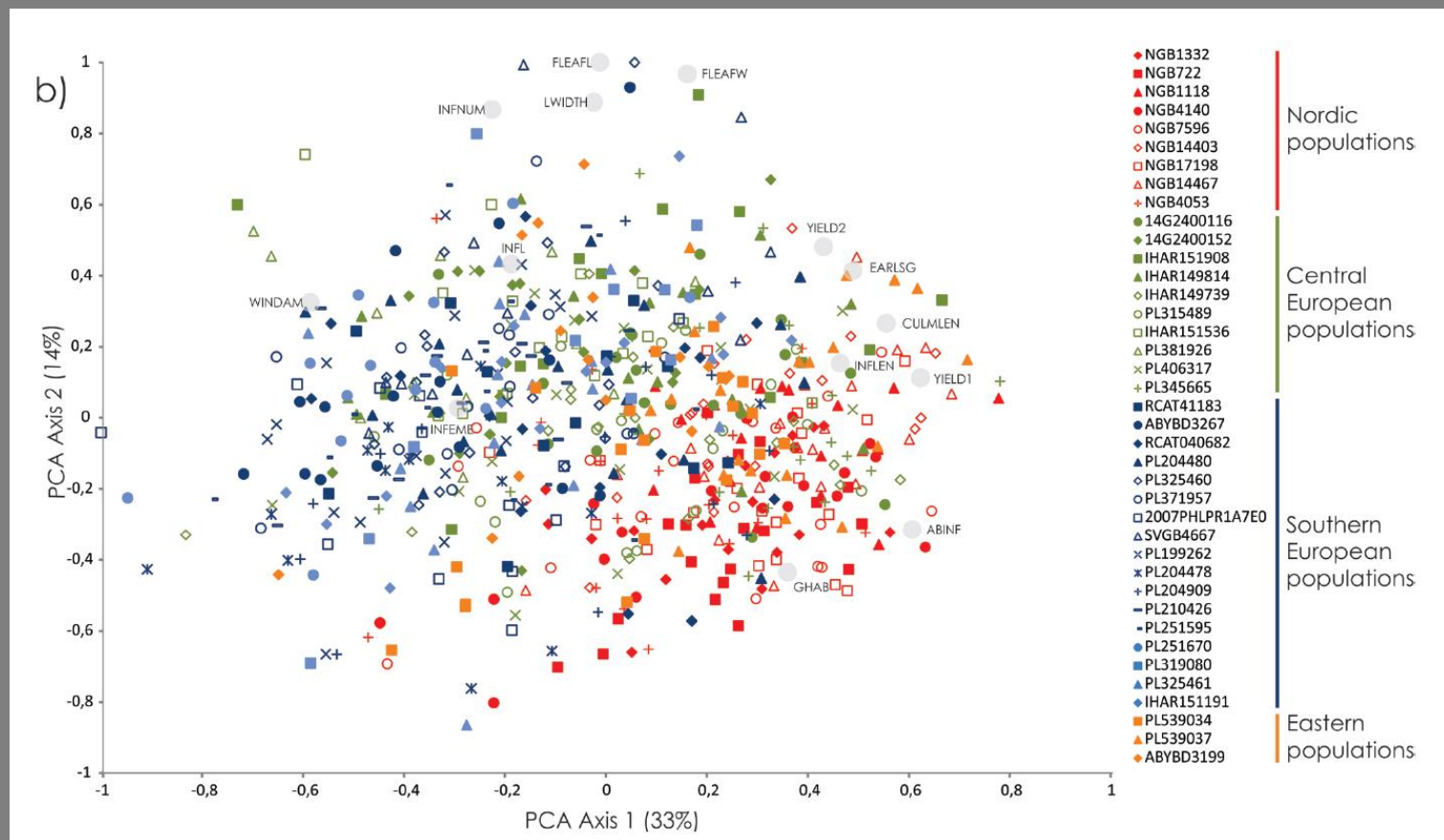
JANUARY



APRIL



LIMITED RISK OF WINTER INJURIES RELATED TO FROST AND ICE ENCASEMENT IN **TIMOTHY** SUFFICIENT VARIABILITY PRESENT TO DEAL WITH THE EXPECTED CHANGES



SITUATION LESS CLEAR FOR THE LESS HARDY
PERENNIAL RYEGRASS / FESTULOLIUM

THE SAME PROBABLY APPLIES TO THE
FODDER LEGUMES

PERENNIAL RYEGRASS AND FESTULOLIUM

GROWN IN THE MILDER LOWLAND
REGIONS SOUTH OF 60°N

SUPERIOR BIOMASS PRODUCTION
AND FODDER QUALITY



POOR WINTER SURVIVAL IN THE NORTH



SUSCEPTABLE TO SNOW MOULD

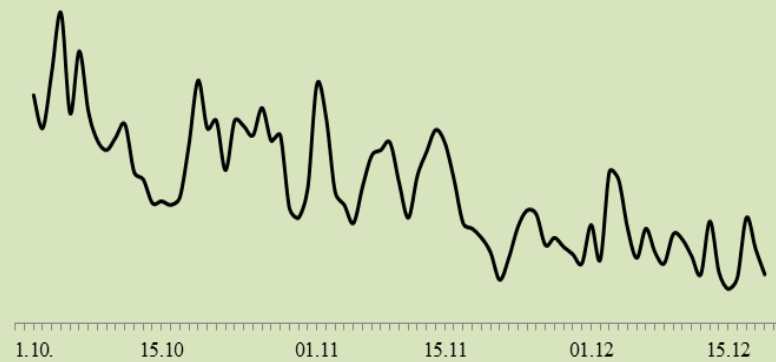
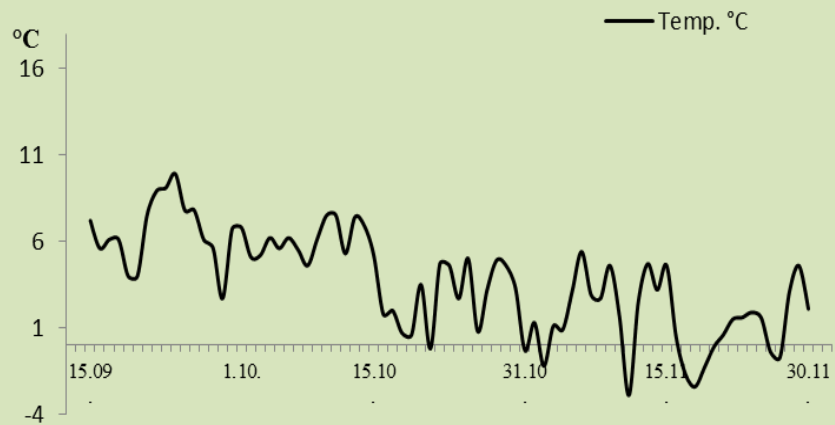
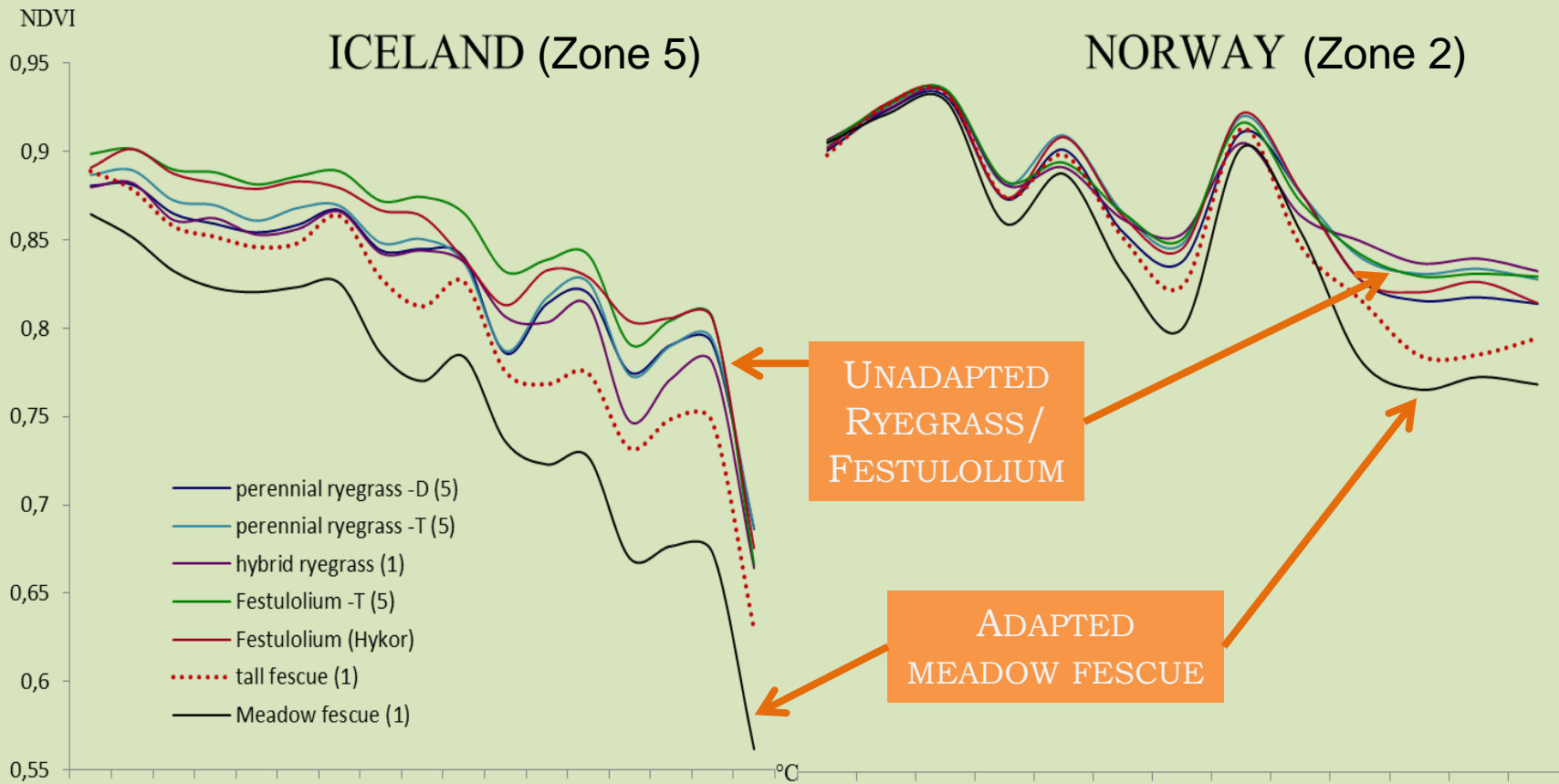
INADEQUATE GROWTH CESSATION IN
AUTUMN FOR SUFFICIENT COLD HARDENING

DE-HARDENS TOO EARLY WITH INCREASED RISK OF
FROST INJURY IN SPRING

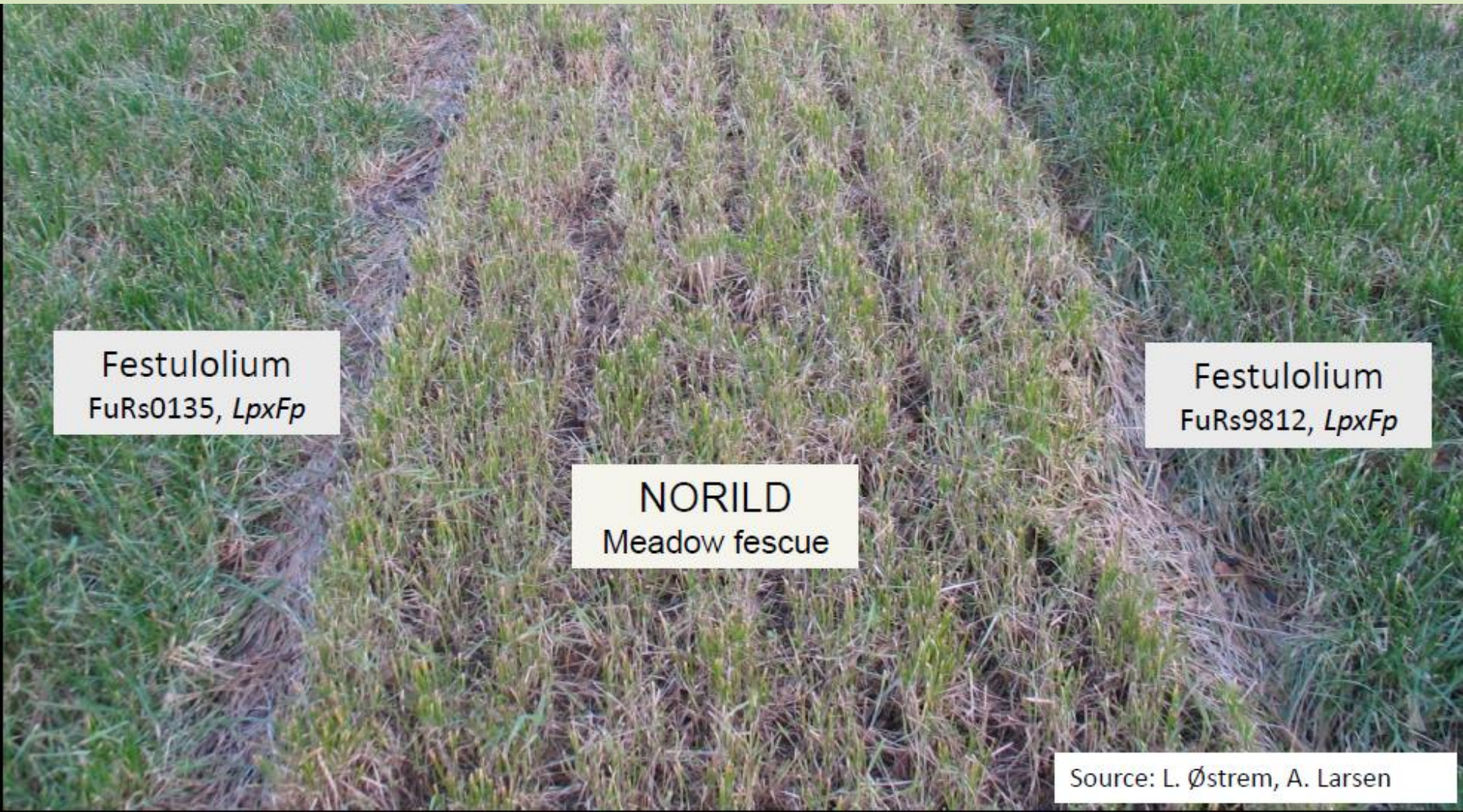
MEASURING AUTUMN REGROWTH

NORMALISED DIFFERENCE VEGETATION INDEX (NDVI)





GROWTH CESSATION IN NORILD IS GOVERNED BY PHOTOPERIOD
NON-ADAPTED POPULATIONS ARE SENSING TEMPERATURE



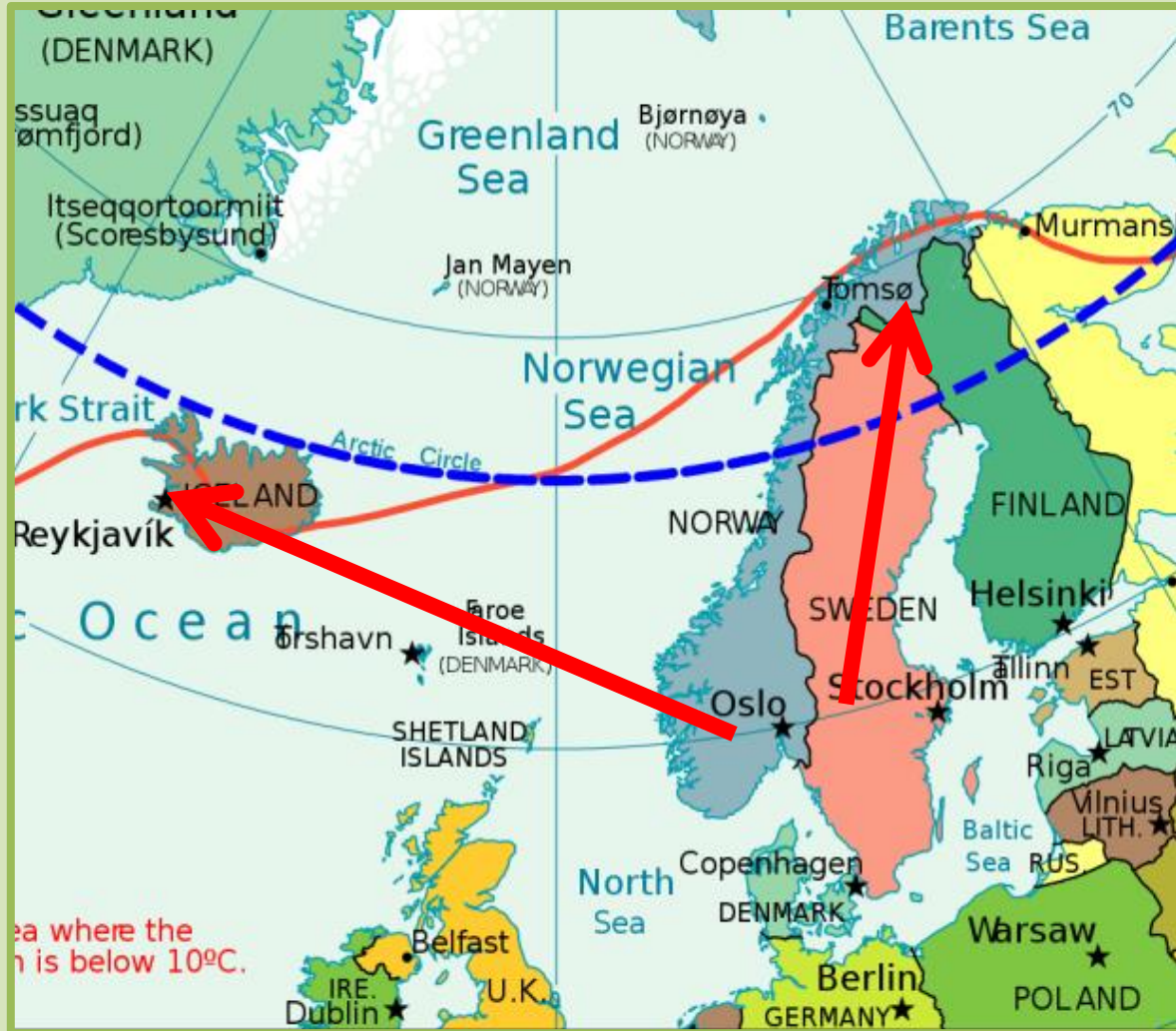
Festulolium
FuRs0135, *LpxFp*

Festulolium
FuRs9812, *LpxFp*

NORILD
Meadow fescue

Source: L. Østrem, A. Larsen

CAN WE EXPAND THE CULTIVATION FURTHER NORTH WITH A WARMER CLIMATE?



MUST IMPROVE
WINTER SURVIVAL

GROWHT CESSATION
IN AUTUMN
MAIN PROBLEM

LOCAL ADAPTATION IS CONTROLLED BY
TEMPERATURE × PHOTOPERIOD

THE PROJECTED CLIMATE WILL LEAD TO
INCREASED TEMPERATURES
BUT THE
SAME SEASONAL PHOTOPERIOD

BREEDING STRATEGY

SELECT GENOTYPES WHERE GROWTH
CESSATION IS CONTROLLED BY
PHOTOPERIOD
RATHER THAN TEMPERATURE YET
PHOTOSYNTHESISE SUFFICIENTLY TO
BUILD UP ENOUGH
RESERVES FOR WINTER

WE NEED TO RECOMBINE

NEW TRAITS FROM

EXOTIC MATERIAL

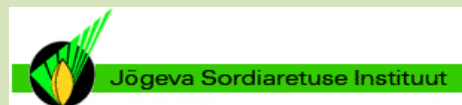
WITH EXISTING BREEDING

POPULATIONS

THE NORDIC PUBLIC PRIVATE PARTNERSHIP FOR PRE-BREEDING IN PLANTS



ADAPTING PERENNIAL RYEGRASS TO NORTHERN CONDITIONS



EXPLOIT EXOTIC MATERIAL TO CREATE NEW VARIATION

Field tests

393 accessions

WP 7
MANY

WP 1
DK

Multiplication

WP 2
DK

Genotyping

WP 6
DK, NO

Phenotyping

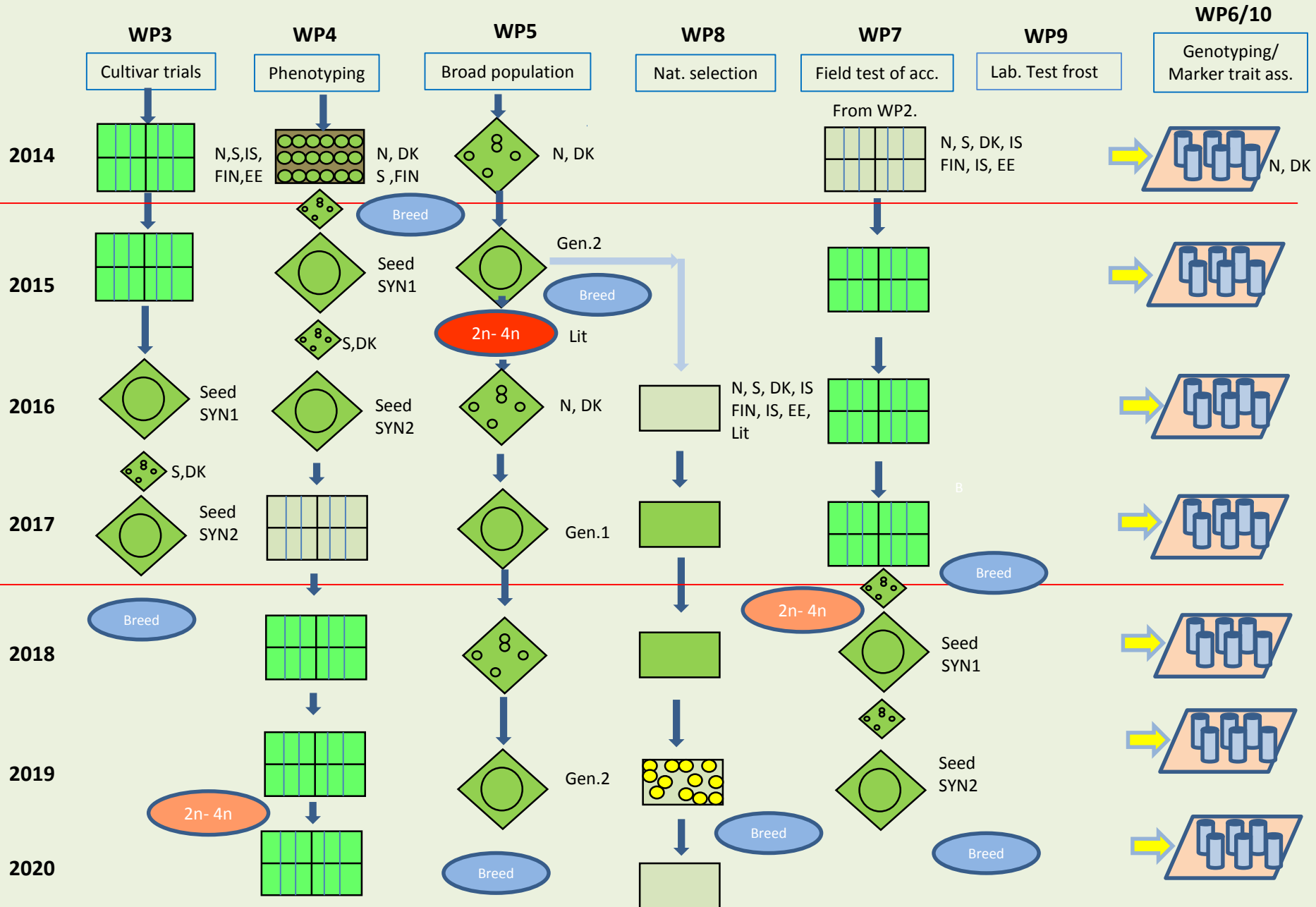
WP 4
DK, NO,
SE, FI

Recombination

WP 4
DK, NO



FLOW-CHART OF THE PPP FOR PRE-BREEDING PROGRAMME IN PERENNIAL RYEGRASS (*LOLIUM PERENNE* L.)

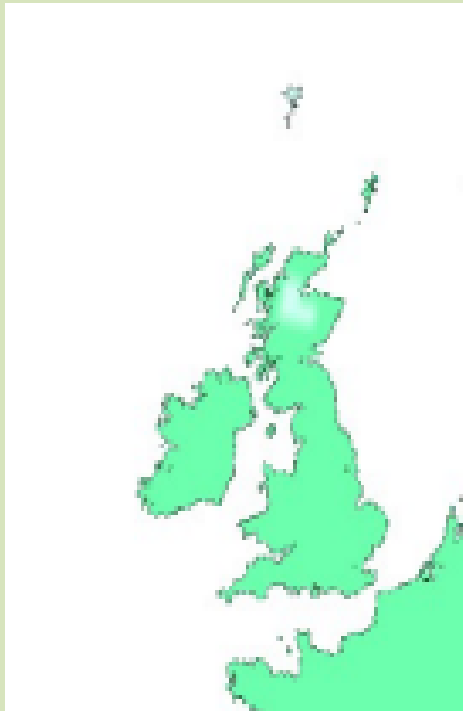


TEMPERATE MARITIME ENVIRONMENT

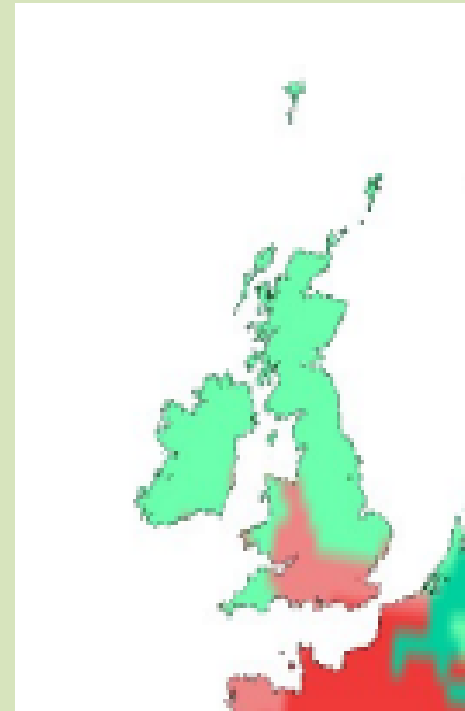


PROJECTED CHANGES

1961-1990



2080



WARMER AND WETTER WINTERS

HOTTER AND DRIER SUMMERS

FUTURE CHALLENGES:

WARMER AND WETTER WINTERS AND HOTTER, DRIER SUMMERS

An aerial photograph of a vast agricultural landscape, likely a rice paddy region, showing a grid of fields in various stages of growth and waterlogging. A large orange arrow points downwards from the top text to the bottom text, indicating a causal link between the climate conditions and the resulting agricultural challenges.

WATERLOGGING, FLOODS, DROUGHTS



SOLUTION:

BREEDING FOR
DEEPER AND MORE
EXTENSIVE
ROOT SYSTEM
WILL IMPROVE
RESISTANCE
TO BOTH
WATERLOGGING
AND **DROUGHT**

EXPLOITATION OF
INTERGENERIC AND
INTERSPECIFIC HYBRIDS

EXAMPLES FROM IBERS (WALES)

FESTULOLIUM



FESTUCA



LOLIUM

FESTULOLIUM PROVIDE OPPORTUNITIES FOR:

- IMPROVED TOLERANCE TO DROUGHTS & COLD
- IMPROVED SOIL STRUCTURES & HYDROLOGY
- FLOOD MITIGATION
- PREVENTION OF SOIL EROSION & LAND-SLIDE
- IMPROVED NUTRIENT USE EFFICIENCY
- C SEQUESTRATION
- REDUCED GREENHOUSE GAS EMISSIONS FROM LIVESTOCK

USING *FESTULOLIUM* FOR FLOOD CONTROL

L. PERENNE

FESTULOLIUM



MORE ROOTS

LARGER ROOTS

DEEPER ROOTS

RAINFALL

L. PERENNE

FESTULOLIUM



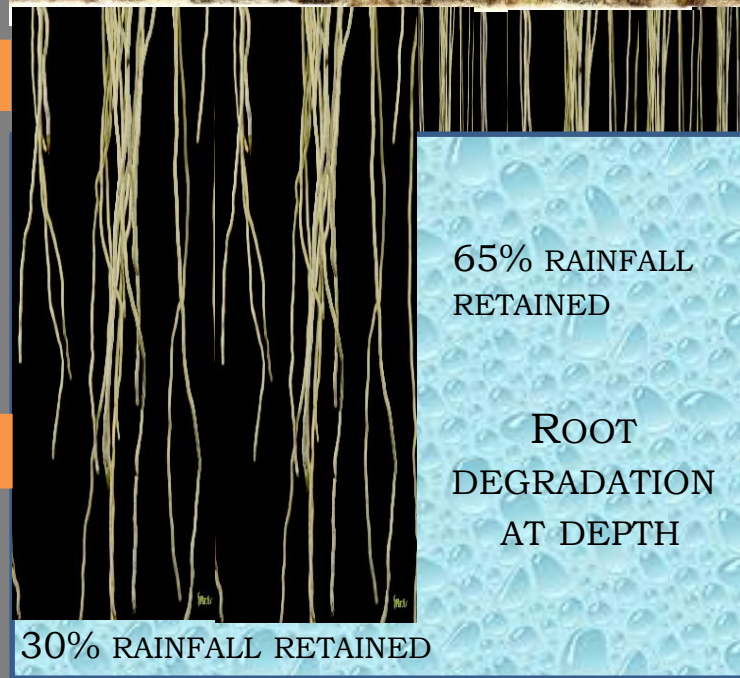
60% RUN-OFF

25% RUN-OFF



TOTAL RUN-OFF
70%

TOTAL RUN-OFF
35%



65% RAINFALL
RETAINED

ROOT
DEGRADATION
AT DEPTH

30% RAINFALL RETAINED

10% RUN-OFF

10% RUN-OFF



NOVEL FESTULOLIUM HYBRIDS - SUREROOT

L. MULTIFLORUM X F. GLAUCESCENS

L. MULTIFLORUM X F. MAIREI

L. PERENNE X F. GLAUCESCENS

L. PERENNE X F. MAIREI



ERECT *L. MULTIFLORUM*



PROSTRATE *L. PERENNE*

INCREASING ROOT DEPTH FOR:

IMPROVED POTENTIAL FOR CARBON SEQUESTRATION

IMPROVED DROUGHT RESISTANCE



INCREASING ROOT STRENGTH TO:

REDUCE SOIL COMPACTION

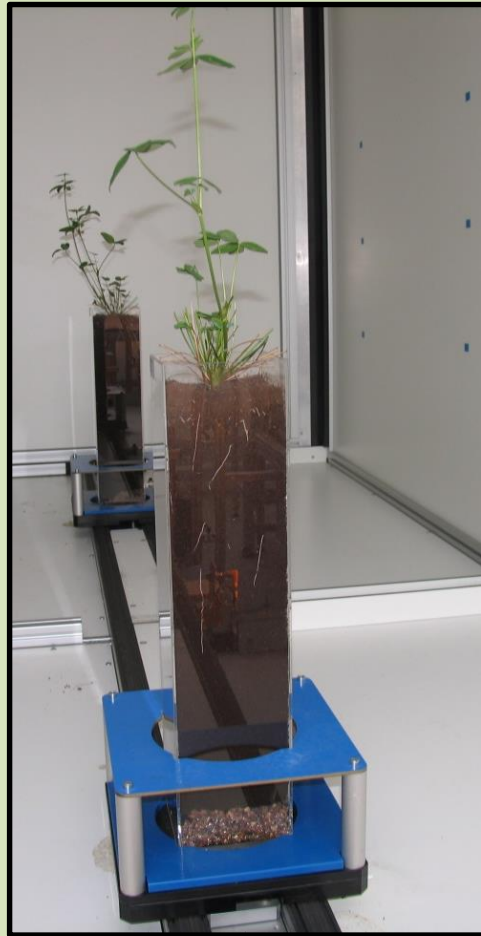
PREVENT EROSION AND LAND-SLIP

IMPROVE ESTABLISHMENT ON HARD LAND SURFACES

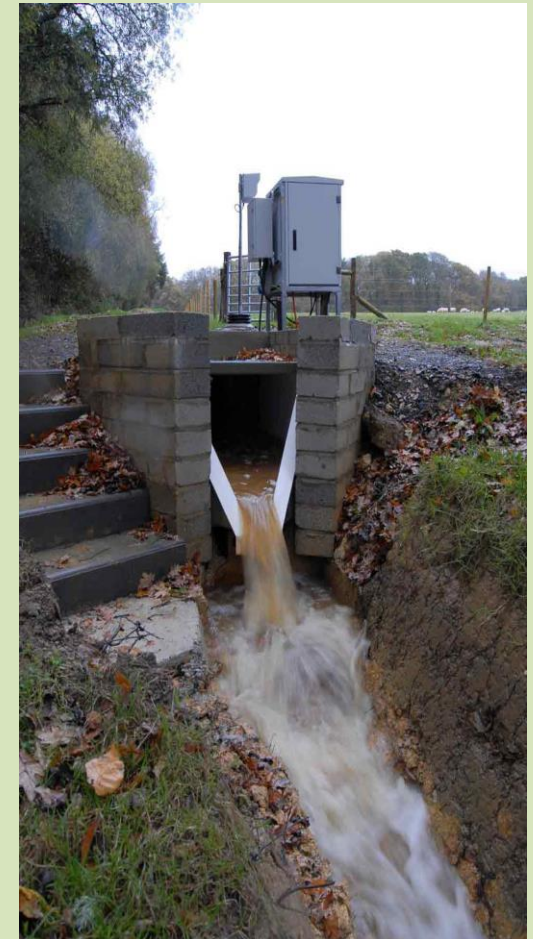


FLOOD MITIGATION

NPPC ABERYSTWYTH



FARM PLATFORM NORTH WYKE



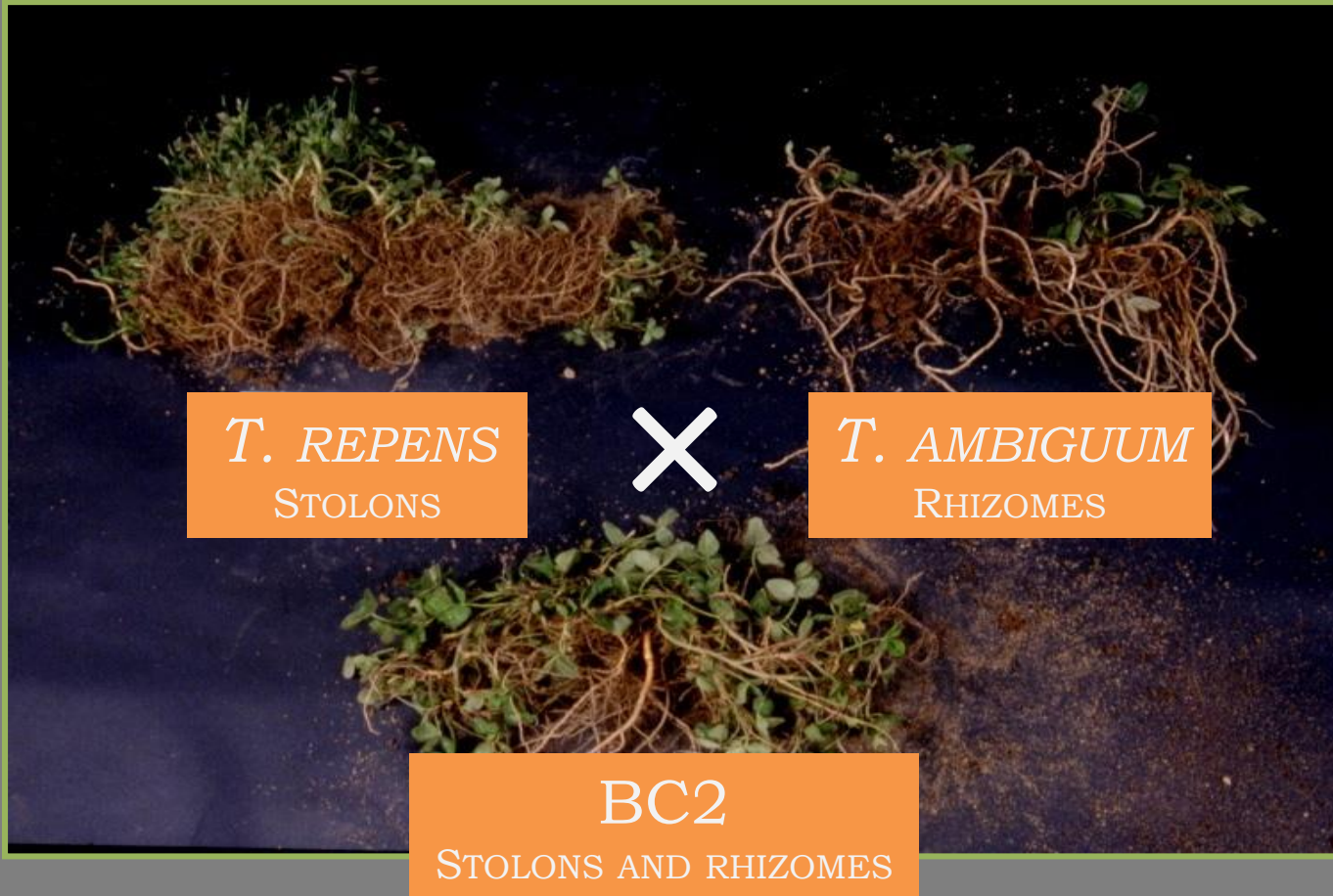
IMPACT OF ROOT ARCHITECTURE AND ONTOGENY



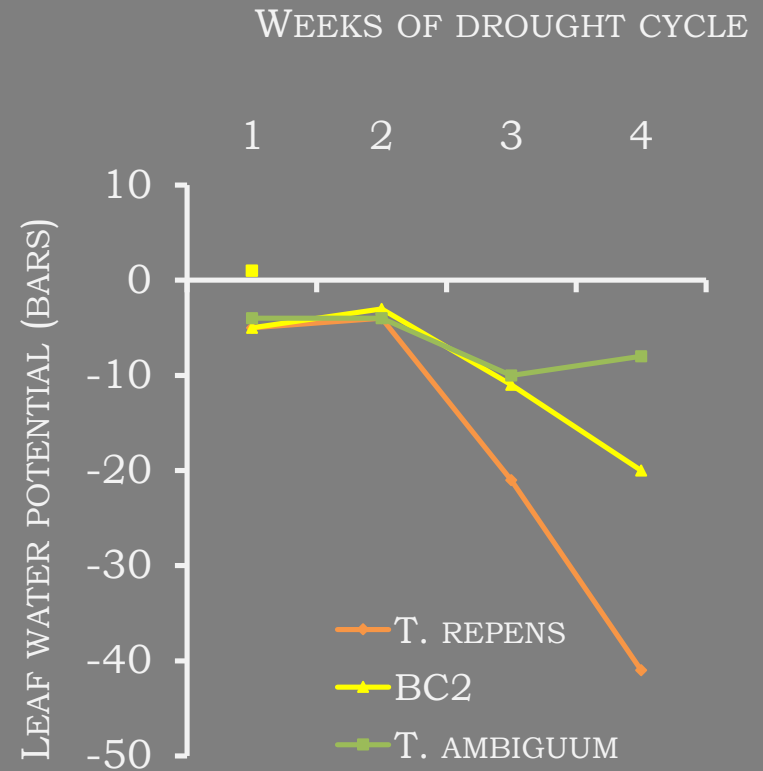
SOIL STRUCTURE
AND HYDROLOGY

DROUGHT TOLERANT WHITE CLOVER

INTERSPECIFIC HYBRIDS



DROUGHT TOLERANCE IN SOIL BINS

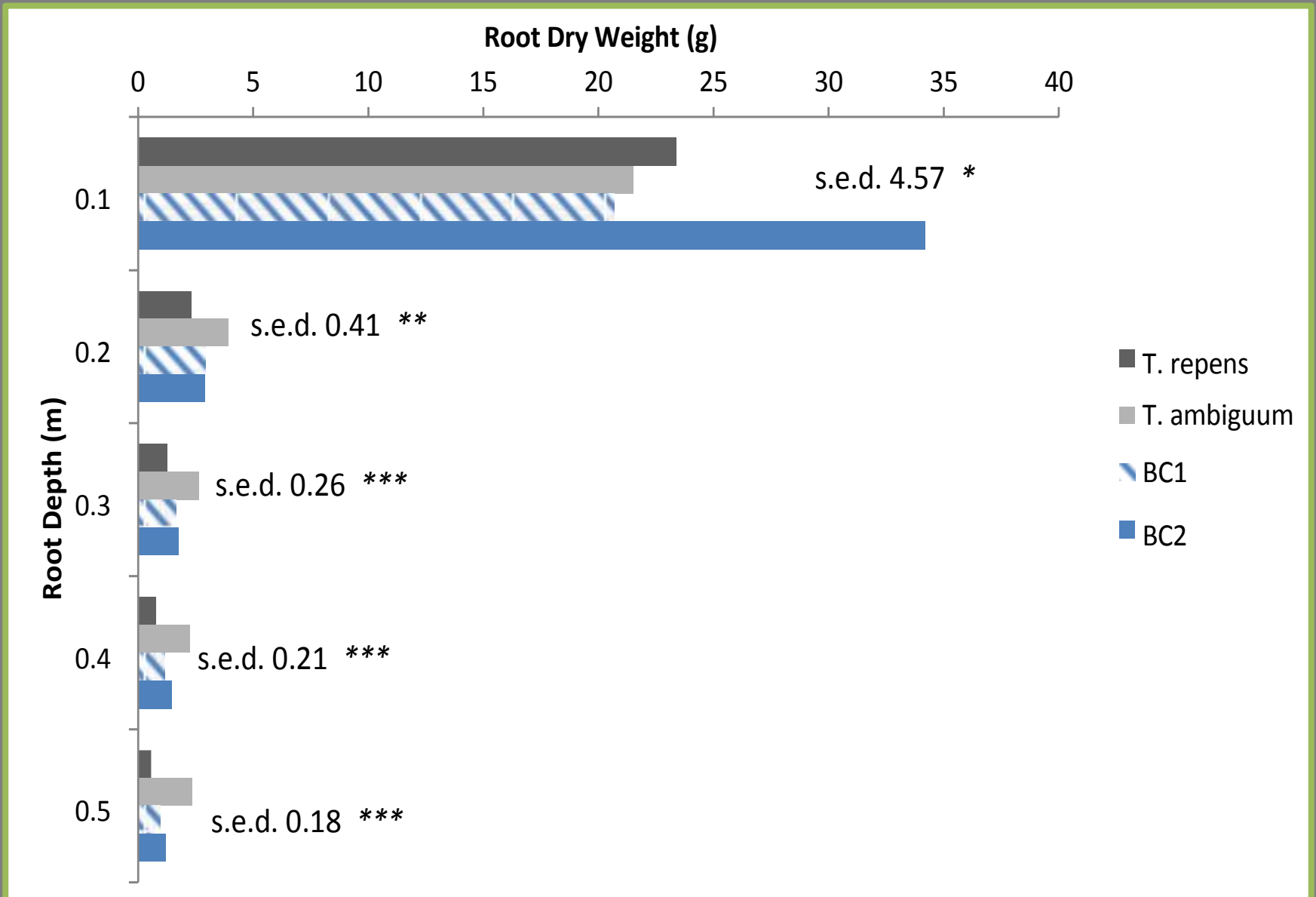


COMPARABLE LEVELS OF SOIL MOISTURE DEFICIT

ROOT ANALYSIS IN PIPES



ROOT WEIGHT DISTRIBUTION – PARENTS AND HYBRIDS



FORAGE YIELD AND QUALITY

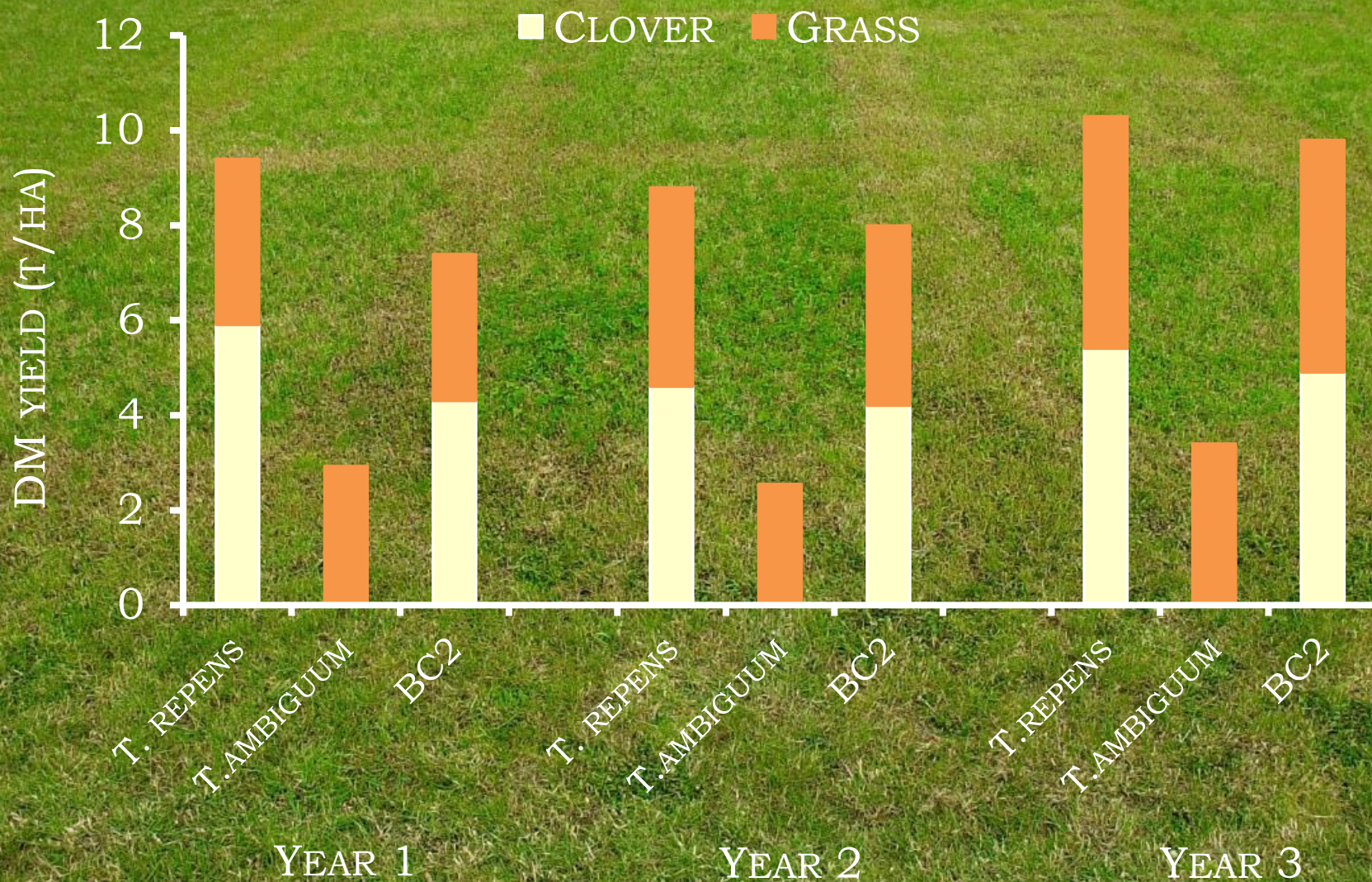
T. AMBIGUUM



T. REPENS

BC1

FORAGE YIELD AND QUALITY

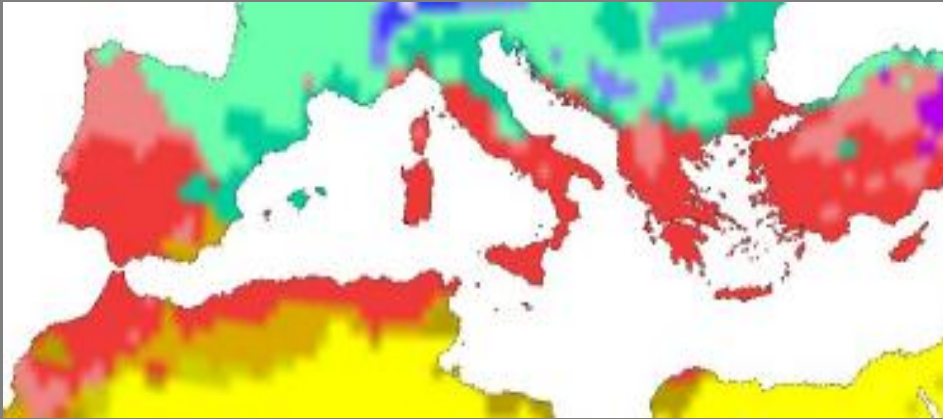


THE SOUTHERN EUROPE ENVIRONMENT



PROJECTED CHANGES

1961-1990



2080

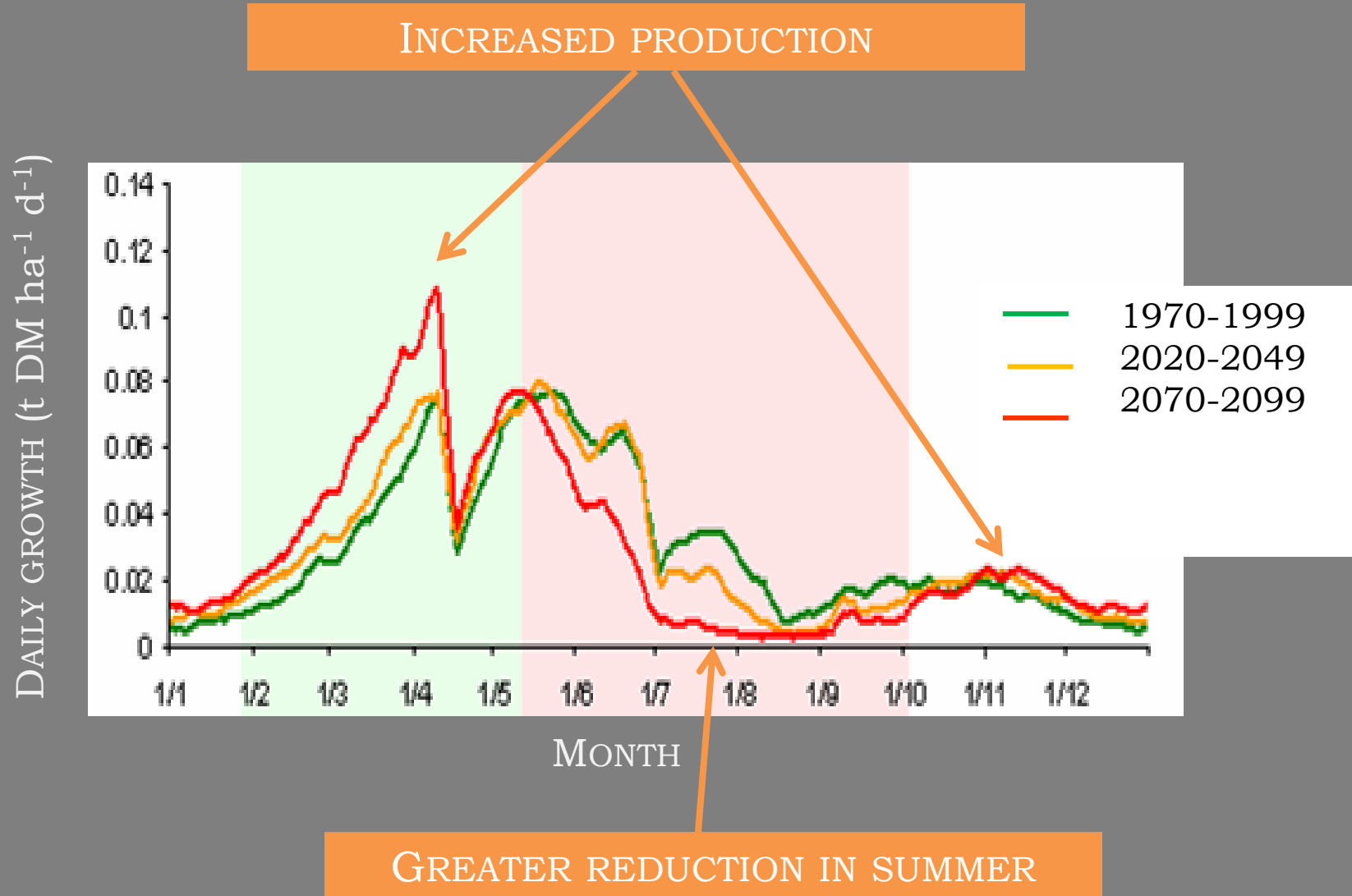


+3-4°C IN SUMMER; +1.5-2°C IN WINTER

LESS RAIN AND HIGHER SOLAR RADIATION IN SUMMER

LIMITED POTENTIAL FOR IRRIGATION

IMPLICATIONS FOR FUTURE FORAGE PRODUCTION



KEY BREEDING ACTIONS

1. CREATE NEW AND BETTER ADAPTED VARIETIES

LUCERNE, TALL FESCUE, COCKSFOOT

LARGE DIVERSITY (ECOTYPES, LANDRACES)
FROM TEMPERATE TO MEDITERRANEAN AREAS



EXAMPLE: LUCERNE

TUNE AUTUMN DORMANCY

DORMANCY SCALE 1-11
1: WINTER DORMANT
11: HIGHLY WINTER
ACTIVE

DEVELOP CULTIVARS FOR RAIN-FED CONDITIONS

CURRENTLY
GROWN:

RANGE 4-5
(FLEMISH)
MOST
BREEDING

RANGE 5-6
(MEDITERRANEAN)
LITTLE BREEDING

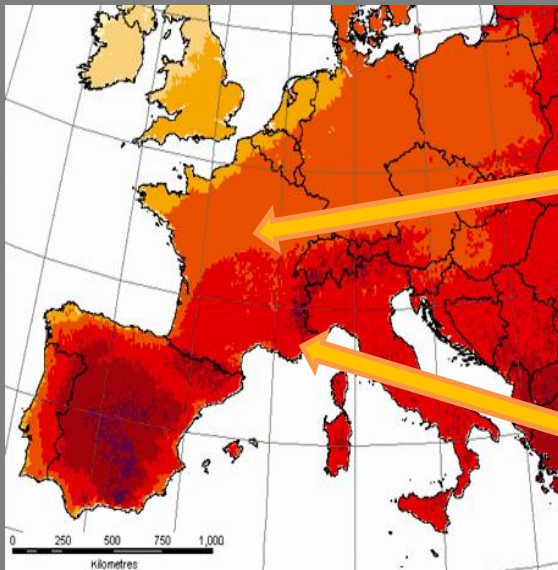
RANGE 7-11
(SOUTH
MEDITERRANEAN)
LITTLE BREEDING
GROWN UNDER
IRRIGATION

TO BE DEVELOPED:

*RANGE 5-6
EFFORTS ON CURRENT CRITERIA
(YIELD, QUALITY, PEST
RESISTANCES, SEED
PRODUCTION)*

*RANGE 7-8
~NO BREEDING IN EUROPE
DROUGHT TOLERANCE*

*RANGE 9-11
~NO BREEDING
DROUGHT TOLERANCE*



2. INCREASE PERSISTENCY OF PERENNIAL GRASSLANDS UNDER SEVERE DROUGHT

THREE STRATEGIES:

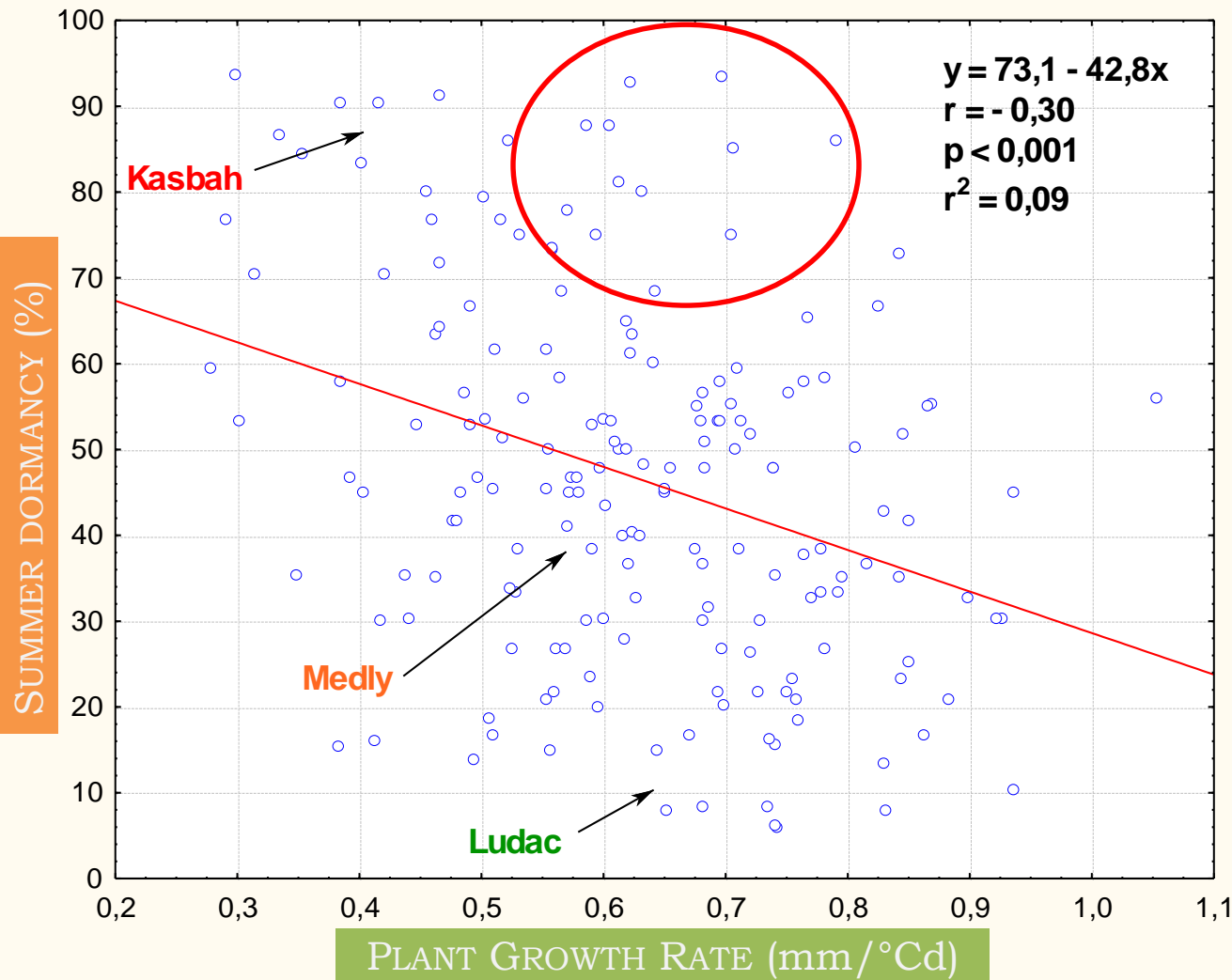
BREED WITHIN NATURAL MEDITERRANEAN POPULATIONS

PYRAMIDE FAVORABLE ALLELES FROM DIFFERENT NATURAL MEDITERRANEAN POPULATIONS

CROSS TEMPERATE ELITE MATERIAL AND NATURAL MEDITERRANEAN POPULATIONS

EXAMPLE: COCKSFOOT

KASBAH × MEDLY



SUMMER
DORMANCY
AND
PLANT GROWTH
RATE
IN A FAVORABLE
ENVIRONMENT
ARE NOT
GENETICALLY
LINKED

3. ENCOURAGE THE USE OF LEGUME SPECIES IN PURE OR MIXED SWARDS IN ROTATIONS

COMPARABLE YIELDS TO THE HIGHEST YIELDING MONOCULTURE WITH LIMITED N

IMPROVED ANNUAL YIELD DISTRIBUTION

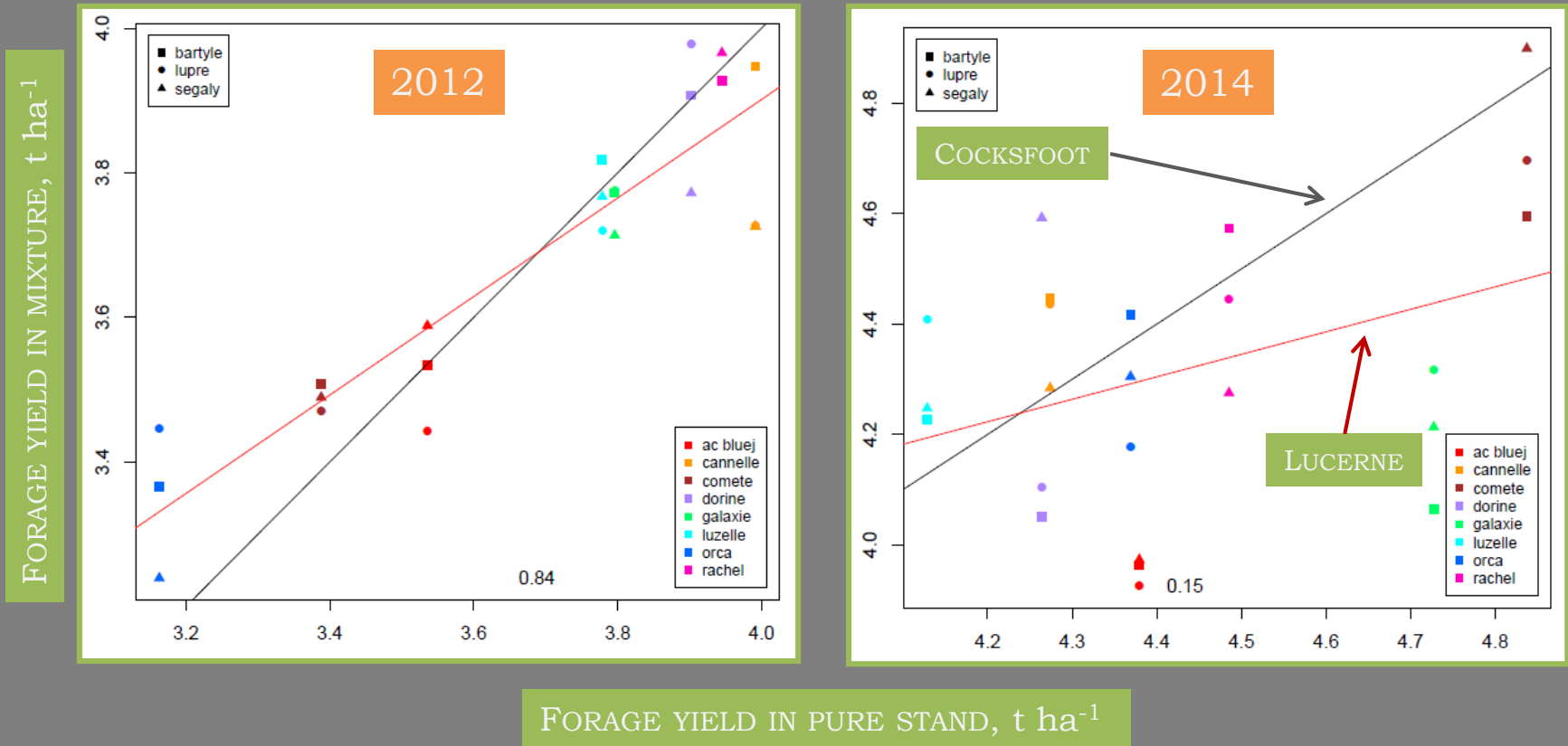
WELL BALANCED N/ENERGY RATIO OF THE FODDER

EXAMPLE

LUCERNE – COCKSFOOT MIXTURES

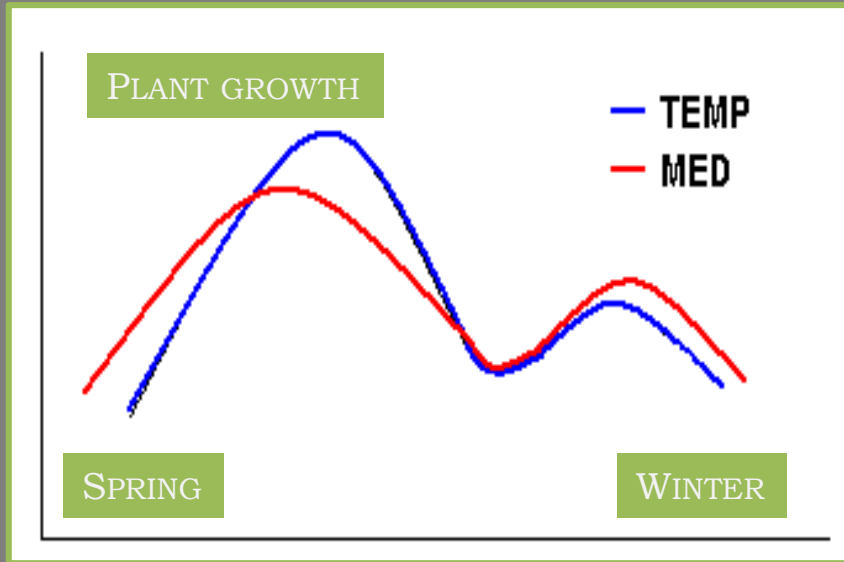
UNTIL NOW: CULTIVARS BRED FOR PURE STAND CROPPING

PROBLEM: POOR CORRELATION FOR LUCERNE WITH MIXTURE PERFORMANCE



ALWAYS CONSIDER MIXTURE PERFORMANCE WHILE BREEDING

MIXING TEMPERATE AND MEDITERRANEAN TYPES

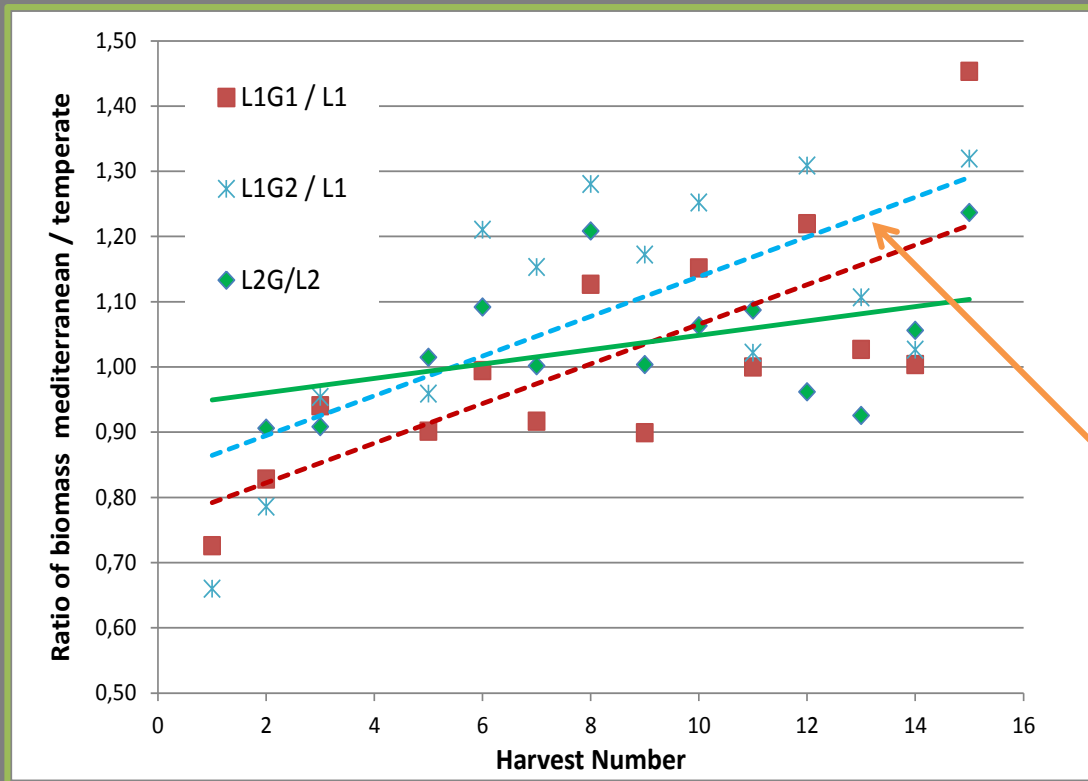


TEMPERATE AND MEDITERRANEAN POPULATIONS DISPLAY GENETIC VARIATION IN SEASONAL GROWTH PATTERNS

CLIMATE CHANGE IS GOING TO PROGRESSIVELY IMPROVE THE WINTER GROWING CONDITIONS

CAN WE USE MEDITERRANEAN AND TEMPERATE GRASS AND LEGUME MIXTURES TO ADAPT FORAGE PRODUCTION TO CLIMATE CHANGE ?

MIXING TEMPERATE AND MEDITERRANEAN TYPES



- IT EXTENDS THE GROWING PERIOD (EARLY SPRING, AUTUMN) AND IMPROVES YIELD STABILITY WITHIN THE YEAR (SPRING, SUMMER, AUTUMN) .
- COMBINING MEDITERRANEAN TALL FESCUE / COCKSFOOT AND TEMPERATE LUCERNE GIVES MIXTURE OVER-YIELDING.

THE JOURNEY AHEAD

BREEDERS HAVE A ROLE TO
PLAY IN ADAPTING FORAGE
CROPS TO THE FUTURE
ENVIRONMENTAL CHALLENGES