Legumes and Biodiversity: key tools for the sustainable improvement of pasture and forage crops in the EU Mediterranean Region under climate change

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Pastures, soils and climate in the EU Mediterranean Region

Traditional pastures/forage crops:

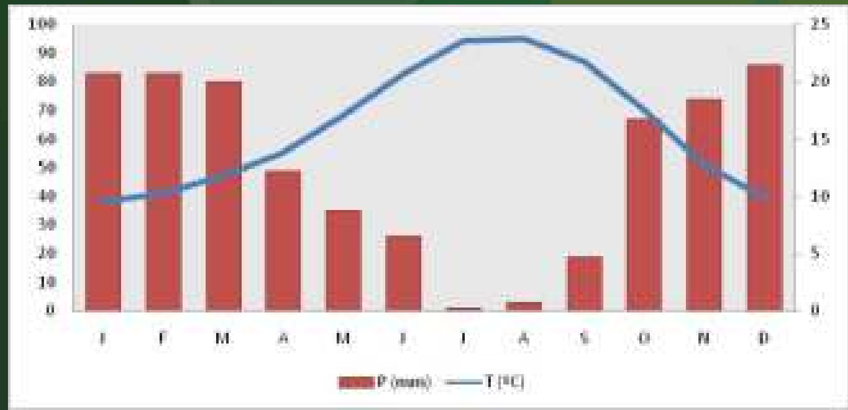
-Most natural pastures are of low productivity;

-Sown pasture and forage crops: cereals (oats, barley, rye, triticale) and ryegrass; little use of legumes

Most soils with natural pastures are:

- Low in organic matter: 0,5 - 1,5%
- Low in nutrients, particularly P
- Shallow and stony
- Low in water holding capacity
- Drainage deficient
- Prone to erosion

There is a need to improve pasture productivity and soil condition



- **Predominant climate:**

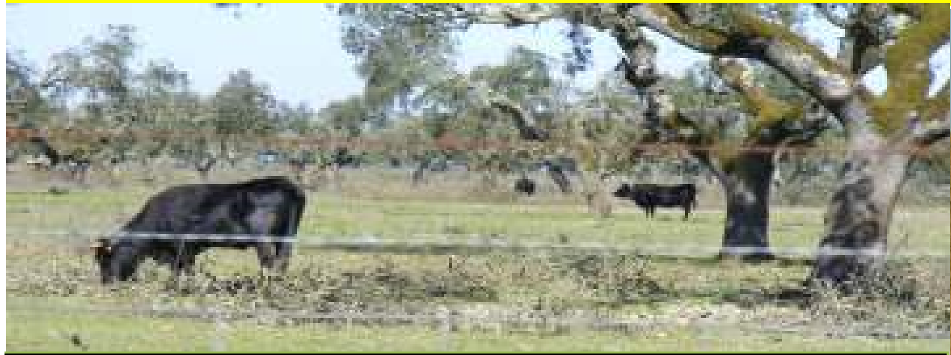
- 2300->3000 hours sunshine/year

-Annual rainfall (300–>1000 mm), >75% falling from Oct. to May

- Mild temperatures in Winter
- Hot and dry Summer

Good to grow legumes

COMMON FEEDING SYSTEM OF RUMINANT ANIMALS IN MOST OF EU MEDITERRANEAN REGION ARE NOT EFFICIENT, BUT CAN BE IMPROVED



Natural pastures, low productivity (grazed from Autumn to Spring/Summer)

Cereal stubbles, grazed in Summer

Straw, as a supplement in Autumn/ Winter; expensive, with low feed value.

Concentrate feed during weaning and fattening: very expensive, mostly imported

FORAGE CROPS for conservation as hay or silage (eventually also for grazing) occupy a small area and involve mainly “gramineae”, whose productivity depends on N fertilizer. Provide expensive feed, often low in protein.

LAND DEGRADATION IN SOME EU MEDITERRANAEAN REGIONS

Subsidized cereals, cultivated with high levels of N fertilizers and herbicides, in short fallow-crop rotations, have…

...degraded natural pastures,

…degraded land, followed by …

… abandonment, shrub invasion…

and destructive fire!

However, <u>most of the EU Mediterranean Region has excellent conditions to grow pastures, which can be grazed all over the year</u>!

HOW CAN THIS BE ACHIEVED IN ASUSTAINABLE FORM, CONSIDERING THE REGION IS SUBJECT TO CLIMATE CHANGE?!

CLIMATE CHANGE IN MEDITERRANEAN AREAS:
NEED TO INCREASE PLANT ADAPTATION/RESILIENCY

- ***Higher frequency of long periods of drought:*** **need to increase water holding capacity of the soils and of more drought resistant plants (annuals with hard seeds, variable length of vegetative cycles, perennials with deeper root systems and/or summer dormancy)**

- ***Concentrated rainfall inducing floods and temporary soil waterlogging:*** **need to improve water infiltration rate in the soils and plants resisting waterlogging**

- ***Raise in air temperature, derived from higher concentration in the atmosphere of GHG, particularly CO2:*** **need for legumes, which grow better under higher temperature and CO2 content in the atmosphere**

- **The above plant adaptation /resiliency requirements can be matched by using <u>Sown Biodiverse Legume Rich Permanent Pasture and Forage Crops (SBLRSPP&FC)</u>, which will improve animal production and recover degraded lands in a sustainable way.**

What are SBLRPP & FC?

65-80% of the area with SBLRPP for grazing complemented with…

…20-35% of the area with BLRFC for conservation

- An efficient and low cost system of pasture and forage production developed in Portugal after the middle sixties, based on the formulation and use of mixtures, each one adapted to a particular soil and climate condition, and composed by a large range of species and cultivars (10 to 20 for permanent pastures, 6-10 for forage crops), mainly of legumes, but also grasses and eventually other plants, chosen among more than 50 species and 150 cvs.; all the species used are of Mediterranean origin, and some have condensed tannins and low methanogenic potential.

Previously to mixing and sowing, the seeds of each legume spp. are inoculated with specific strains of *Rhizobium…*

…to enhance symbiotic N fixation (60-200 kg N/ha/yr making these crops self sufficient in N

Fundaments:

Mediterranean Region is the Centre of Origin of a great number of herbage legume species, most of which are annuals with hard seeds , and some others are perennial with deep root systems or summer dormancy.

Legumes :

- are able to fix high amounts of symbiotic N;

- are rich in protein (a limiting factor in the traditional Mediterranean pastures and forage crops);

- have superior intake, originating higher animal production performance ;

Biodiversity: confers better adaptation to soil and climate variation, increases productivity and persistence

BIODIVERSE LEGUME RICH MIXTURES:

- **minimize the effects of climate change;**
- **assure a good vegetation cover in patchy soil conditions;**
- **minimize the effects of grazing mismanagement.**

PLANT ADAPTATION TO DIFFERENT PATERNS OF RAINFALL

According to the length of the vegetative cycle of self reseeding annual species (with hard seeds):

(Examples, as observed at Herdade dos Esquerdos, Fertiprado, Vaiamonte, Portugal)

Nº of days from germination to flowering for the earliest and the latest variety (in brackets), and intervals between them, for some of the species used in BLRSPP:

- ***Trifolium subterraneum*** (111-189)- 78 days between the earliest and latest
- ***Trifolium michelianum*** (128-187)- 59 days
- ***Trifolium resupinatum*** (161-196)- 35 days
- ***Trifolium vesiculosum*** (180-208)- 28 days
- ***Trifolium isthmocarpum*** (185-209)- 25 days

- ***Medicago polymorpha*** (114-184)- 70 days
- ***Medicago scutellata*** (104-133)- 29 days

- ***Ornithopus compressus*** (134-184)- 50 days
- ***Ornithopus sativus*** (148-191)- 43 days

- ***Biserrula pelecinus*** (133-184)- 51 days

PLANT RESILIENCY TO DROUGHT (examples)

Persistence (after 6 years) of some perennial species under rainfed conditions at Fertiprado's experimental site

(Herdade dos Esquerdos, Vaiamonte, Portugal)

Mean annual rainfall- 590 mm, varying in the period from 303 to 726 mm

Legumes	2007 (nº of cvs. tested)	2013 (% surviving)	Grasses	2007 (Nº of cvs. tested)	2013 (% surviving)
Medicago sativa	16	100	*Phalaris aquatica*	4	100
Trifolium ambiguum	1	100	*Festuca arundinacea*	27	93
Trifolium fragiferum	2	50	*Dactylis glomerata*	17	70
Lotus pedunculatus	2	50	*Lolium perenne*	25	4
Lotus tenuis	3	33			
Lotus corniculatus	4	25			
Trifolium repens	13	0			

PLANT RESILIENCY TO WATERLOGGING

Examples of waterlogging resistant species:

-Legumes:*Lotus pedunculatus, Trifolium fragiferum, T. isthmocarpum, T. resupinatum, T. michelianum, T. subterraneum spp. yanninicum.*

-Grasses: *Holcus lanatus, Phalaris aquatica, Festuca arundinacea, Lolium perenne*

However, SBLRPP&FC are not only better adapted to Climate Change, they have also a mitigating effect on it, by:

- ***Sequestering atmospheric CO_2 in the soil:***

  SBLRPP may sequester 3-12 t of atmospheric CO_2/ha/year in the 0-10 cm top soil layer, and 50-60% of that in the 10-20 cm layer, the lower figures being associated with older pastures having a SOM content above 4%.

  BLRFC , although less efficient in C sequestration (because they are annual crops and used mainly to produce conserved forage) if sown through minimum tillage methods, may also sequester significant amounts of CO_2.

***Replacing nitrogen fertilizers by atmospheric N fixation (legume/Rhizobium symbiosis)*:**

Each kg of N produced industrially involves an emission of 8 kg CO_2 to the atmosphere. Therefore, replacing traditional pastures/forage crops by SBLRPP&FC, may represent an economy of 60-130 kg of synthetic N/ha/year, corresponding to a reduction of CO_2 emissions varying from 480 to 1040 kg/ha/year.

Carbon sequestration in the soil through SBLRPP:

- Dead roots (most of the species are reseeding annuals)
- Senescent stems, leaves, and pasture residues s not consumed
- Animal faeces
- Raise the level of soil organic matter (SOM), increasing soil fertility and acting as a carbon sink

Some results on Carbon sequestration inthe soil layer 0-10 cm

(SBLRPP vs. NP)

METHOD OF SEED BED PREPARATION FOR PASTURE ESTABLISHMENT	TYPE OF PASTURE	SOIL ORGANIC MATTER (%)				MEAN ANNUAL VARIATION (%/year)	MEAN CARBON SEQUESTRATION (t CO_2/ ha/ year)
		Year 1	Year 2	Year 3	Year 4		
Minimum tillage	Natural	0,84	1,06	1,10	1,45	0,20	5,95
	BLRP	0,80	1,40	1,54	2,08	0,43	12,80

Source: Project Agro 87: "Pastagens Biodiversas Ricas em Leguminosas: uma alternativa sustentável para o uso de solos marginais", INIA, Elvas, Portugal.

Other SBLRPP&FC advantages:

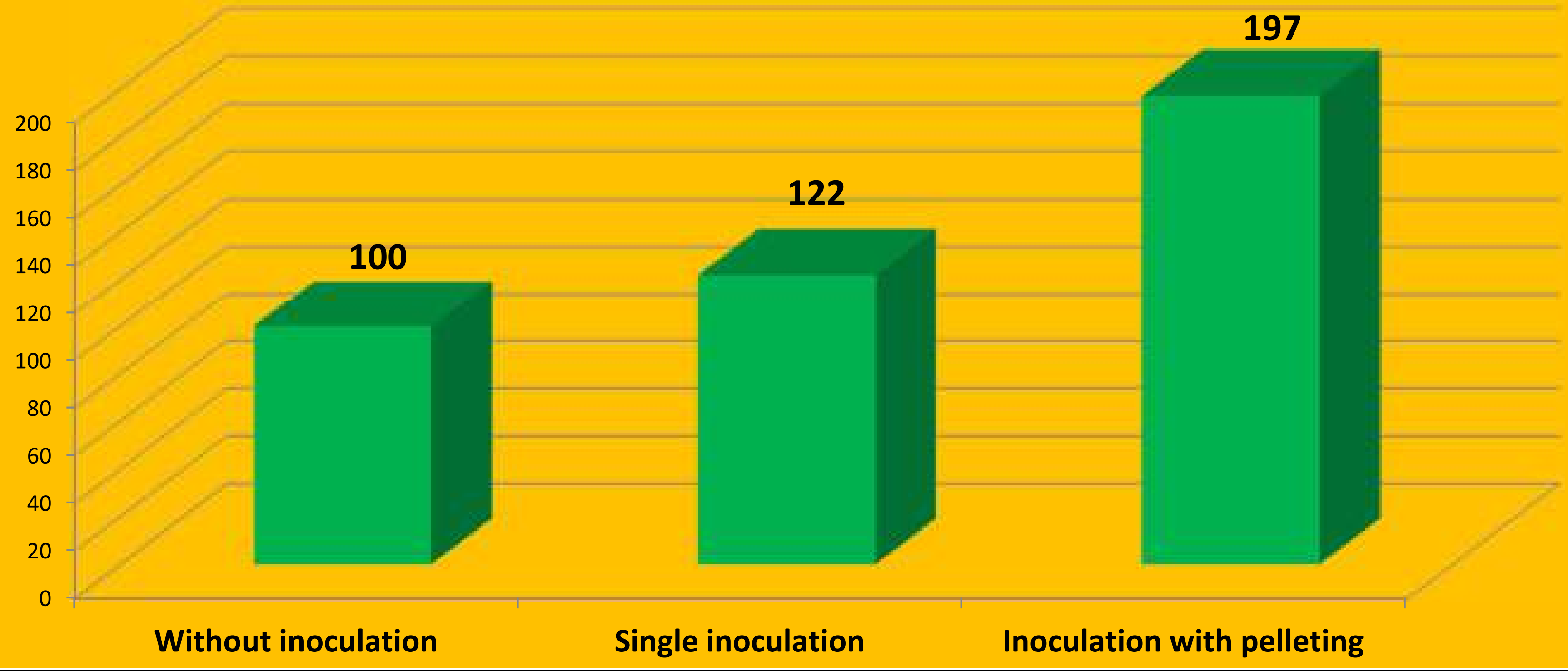
- **Low fossil energy required:** established through minimum tillage; no N fertilizers needed; long lasting permanent pasture utilized through grazing all over the year, with 65-80 % of the ingested minerals returned to the soil through the animal faeces and urine
- **Efficient photosynthesis** due to their **higher leaf area index**
- **Better uptake of soil nutrients** because of their denser and deeper root system

IN ADDITION: better landscapes, higher biodiversity; increased soil fertility, less soil erosion; higher water infiltration rate in the soil; less floods; increased water quality; less fires; more meat and milk of higher quality produced locally; less dependence on concentrate feed (mostly imported , expensive, and with a high C foot print)

Requirements for the success of SBLRPP& FC:

1. Before mixing, **inoculate the seeds of each legume species with specific and effective strains of Rhizobium**, to maximize symbiotic nitrogen fixation (up to 200 kg N/ha/yr under rainfed conditions and up to 500 kg N/ha/yr under irrigation).

-Such a seed treatment should use adequate technology:



Relative yields of subterranean clover in response to two different methods of seed inoculation.

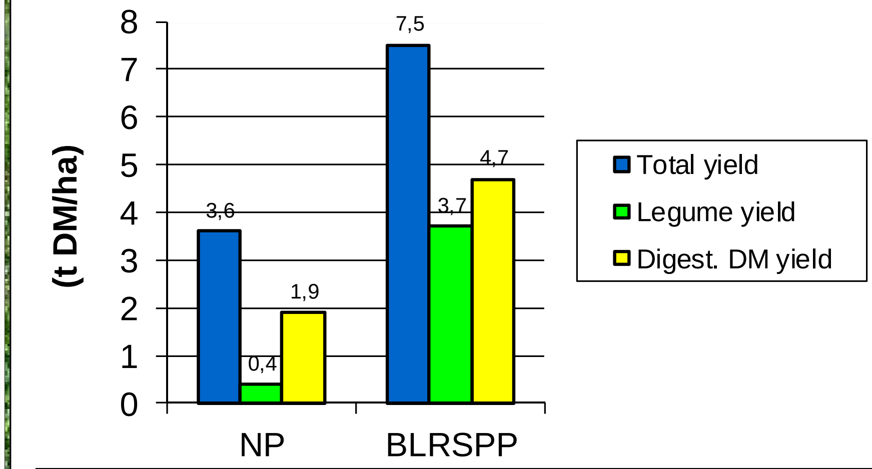
2. **Early sowing:** soil temperature >12ºC; ideally>16 º

3. **Rational use of fertilizers:** according to soil analysis -

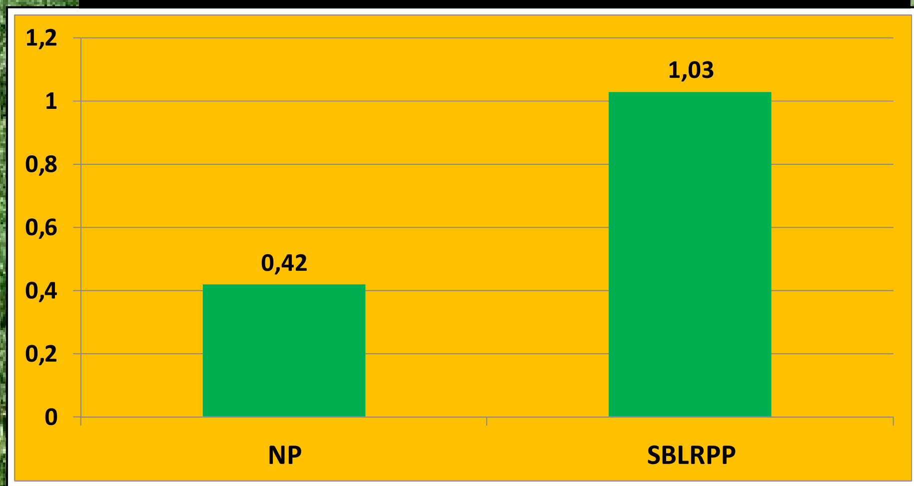
Fertilization: self-sufficient in **N**, but requiring other macro-nutrients, particularly **P**, eventually also **K**, **Ca, S, Mg**, or micro-nutrients (**Mo**, B, Zn, Mn, Cu, Fe, Co).

Herbage production, quality and carrying capacity
Comparison between natural pastures (NP) and SBLRPP

Total, legume and digestible DM yields (2 yrs. average from 3 experimental farm units).



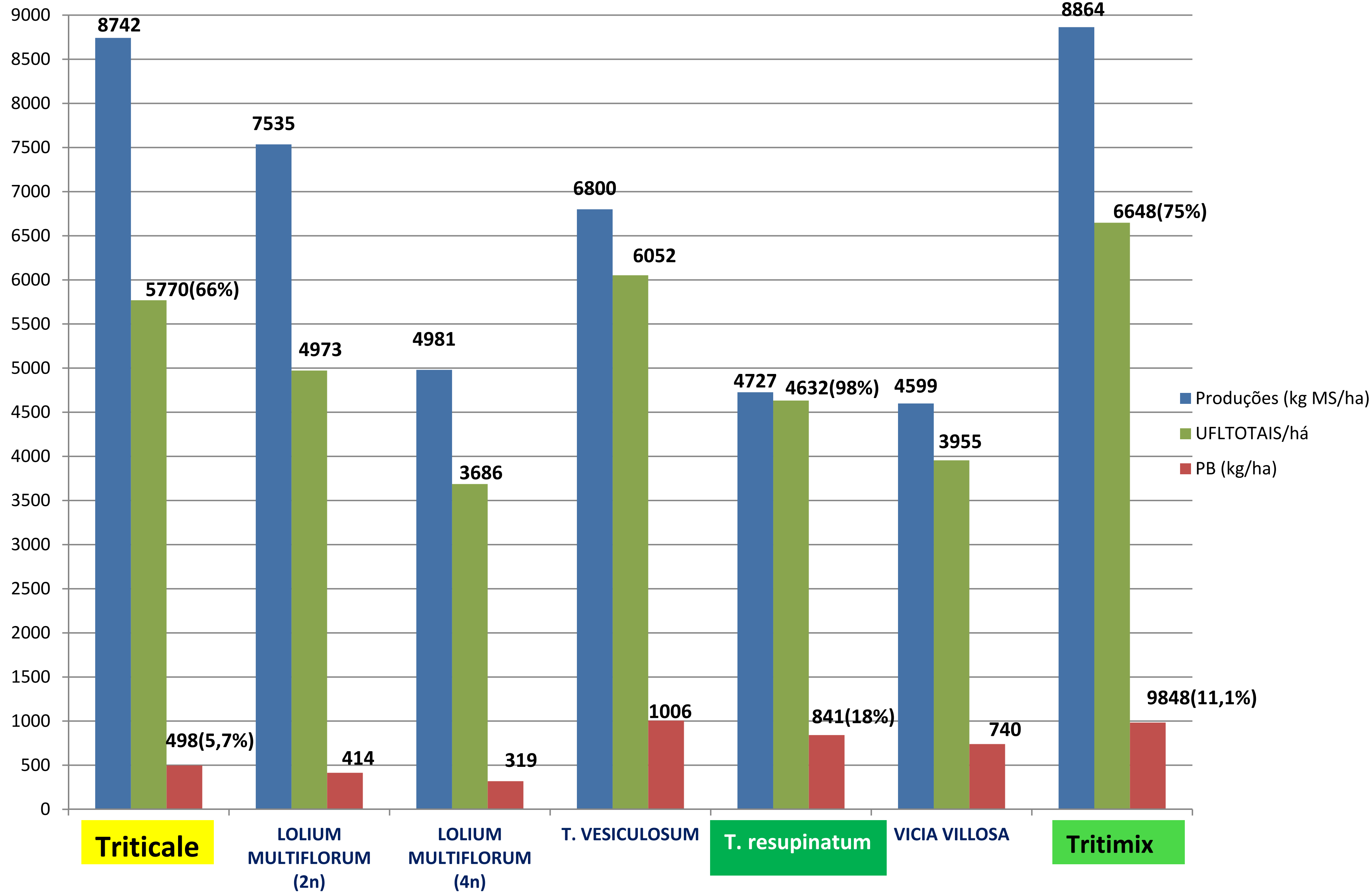
Carrying capacity (CU/ha/year): 3 yrs average from 6 experimental farm units



Source: Projecto Agro 87 - "Pastagens Biodiversas Ricas em Leguminosas: uma alternativa sustentável para o uso de solos marginais", INIA, Elvas, Portugal

Comparing yield and quality of a BLRFC (TRITIMIX) with its components

Comparing yield and quality of a BLRFC (TRITIMIX) with each one of its components
Vaiamonte, Portugal, rainfed conditions, single cut on 4th May 2011



FINAL REMARKS

- From 1966 up to now, more than 500,000 hectares of SBLRPP have been established, mainly in Portugal but also in Spain and Italy, most of them still persisting.
- These pastures, complemented by BLRFC, are allowing a sustainable improvement of high quality animal production at low cost, and also contributing to decrease the amount of GHG in the atmosphere through the sequestration in the soil of 3-12 t/ha/yr of atmospheric CO_2/ha/yr , thus increasing soil fertility.
- There are more than 20 million ha of natural pastures in the EU Mediterranean countries, a significant part of which can be converted into SBLRPP, in order to increase the production of high quality meat (and milk) on grazed pastures and, simultaneously, minimize the consumption of concentrate feed and synthetic N fertilizers.