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Rita A. M. Melis, Bernadette Julier, Luciano Pecetti, Imane Thami-Alami, Khaled Abbas, Meriem Laouar, Aissa Abdelguerfi, Taoufik Hayek, Gregoire Aubert, Paolo Annicchiarico, et al.

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Project REFORMA

'Resilient, water- and energy-Efficient FORage and feed crops for Mediterranean Agricultural systems'



Lucerne crop in drought-prone environments



Edited by: Claudio Porqueddu, Rita A. M. Melis

Authors of the text: Rita A. M. Melis, Bernadette Julier, Luciano Pecetti, Imane Thami-Alami, Khaled Abbas, Meriem Laouar, Aissa Abdelguerfi, Taoufik Hayek, Aziz Bouizgaren, Paolo Annicchiarico, Claudio Porqueddu

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Lucerne, the ultimate forage legume

Lucerne is a forage legume known for its high content in proteins, fibers of good quality, vitamins and pigments. It is mainly used as hay or dehydrated meal. It does not contain anti-nutritional factors for ruminants although its fresh use may require some caution because of risk of bloat. Lucerne is essential in the cattle diet, especially for dairy cows, but it is also used for small ruminants and horses.



Figure 1. Lucerne in an olive grove in Mareth Oases (South Tunisia), 2014.

Crop spread

Lucerne is widely cultivated in all climatic areas of the world, except under tropical climate. Major producing areas are North and South America and Europe. Only 3% of the world surface is grown in Africa, but the crop is important in North-African countries, where it is grown under irrigation. In Morocco, 106000 ha are cultivated with lucerne (22.8% of country's total fodder crop land) and 36000 ha in Egypt. In Algeria, lucerne

covers about 10000 ha. Lucerne is the main forage in Tunisia, where it is grown over about 13000 ha (77% in oases). The small area planted in Mauritania is concentrated in oases.

Advantages and limitations of lucerne

Lucerne is a temporary grassland (3-5 years) repeatedly harvested each year, which shows the highest protein production per hectare. Its deep rooting system makes lucerne tolerate the drought stress (up to 150-200 mm of water deficit in soil). Like other legumes, its root nodules contain bacteria, *Sinorhizobium meliloti*, with the ability to fix nitrogen, producing a high-protein feed regardless of available nitrogen in the soil.

Lucerne has a flexible management, in fact it can be grown up for hay production or silage, dehydration or grazing. The main limitations of lucerne crop are the low yield and/or persistence under severe water stress and under grazing. Moreover, it is not

adapted to cope with high cutting frequency. Its weed control is sometimes problematic during cultivation.

Environmental benefits

Better soil structure, increased soil fertility by nitrogen fixation, lower soil erosion and greater soil biodiversity are common environmental benefits obtained with lucerne cultivation.

Where it grows

Lucerne performs well in deep and well-drained soils. Crusty or waterlogged soils should be avoided as well as acid soils, where high levels of aluminum and manganese are present (they are toxic to lucerne) and sandy soils, where potassium and phosphorous are scarce or easily leached out. The minimum environmental requirements for lucerne growth are summarized in table 1. The maximum temperature for growth is 35-40 °C.

Table 1. Minimum environmental requirements for the growth of lucerne

Environmental parameter	minimum	optimum
Rainfall (mm)	350	600
Day temperature (°C)	5	15 to 25
Night temperature (°C)	–2 to –5	10 to 20
Soil pH	6.0	7.5

Varieties: a limited choice for drought-prone environments

Lucerne varieties are usually distinguished by their winter dormancy based on their cool-season vegetative activity. Mild-winter, Mediterranean environments require the use of non-dormant varieties (dormancy range between 6 to 11 on the NAAIC scale, <http://www.naaic.org/stdtests/Dormancy2.html>) able to grow in autumn and winter and exploit the long vegetative season. Non-dormant varieties are highly productive in this condition. Currently, breeding is less active for non-dormant than for dormant varieties because of more restricted seed market. Variety choice is thus relatively limited.

The proper variety choice depends on:

- The availability of seed and the market seed prices
- The pedo-climatic conditions: need of adapted varieties to major constraints of dryland farming systems in Mediterranean environments (e.g., drought, salinity).
- The disease and pest resistance
- The destination of stand (hay or grazing): intensive grazing with short resting periods may require specifically adapted varieties.

Table 2. Some interesting varieties tested in dryland Mediterranean environments

Name	Cold-season dormancy score ^a	Promising traits	Seed company
SARDI 10	10	Well adapted to a range of Mediterranean conditions, except in the presence of saline soils	Heritage Seeds (www.heritageseeds.com.au)
Siriver	9	Good adaptation to moderately drought-prone environments	Seedmark (www.seedmark.com.au)
Bulldog 805	8	Dual purpose for hay and grazing, with good grazing tolerance; adapted to drought-prone environments	Athens Seed Company (www.athensseed.com)
AmeriStand 801S	8	Outstanding adaptation to saline growing conditions; adapted to drought-prone environments	America's Alfalfa (www.americasalfalfa.com)
Barmed	7.2	Released in 2002	Barenbrug Holland BV (NL)
Zénith	7.1	Released in 2001	Ets Florimond Desprez (FR)
Verdor	6.9	Released in 2011	Barenbrug Holland BV (NL)
Dorine	6.5	Medium-high tolerance to lodging. Released in 2001	Barenbrug Holland BV (NL)
Soraya	6.3	Released in 2012	Barenbrug Holland BV (NL)
Medoc	5.7	Released in 2013	Jouffray-Drillaud SA (FR)
Tampico	5.6	Released in 2013	Cal/West Seeds (CA)
Occitane	6.0	Tolerance to stem nematode and anthracnose Released in 2016	Gie Grass (FR)

^a 1: highest dormancy score; 11: lowest dormancy score



Figure 2. Lucerne crop for seed production

Seed: choose the quality

Seeds produced from locally adapted populations are still commonly used, but the use of certified seeds of selected varieties, when available, is advisable. Certified seeds guarantee seed vigor and germinability, are disease-free and have a high seed purity. Moreover, seeds are parasite free (no dodder/*cuscuta*).

Seed inoculation and coating

Inoculation is essential in soils with $\text{pH} < 6$. In all cases, inoculation makes the nodulation easier. Specific inoculants based on *Sinorhizobium meliloti* are available in the market (e.g. Nodular alfa, Actileg Erba medica in Italy, Inoculum Luzerne NPPL Tourbe or Rhizactiv in France). As an alternative, pelletized or coated seeds are available. The coat can consist of a rhizobium-peat mixture, a lime coating, a fungicide, or a combination of fungicides to protect the seeds from root rot (*Pythium* spp. and *Phytophthora* spp.) and anthracnose (*Colletotrichum trifolii*).

Stand establishment: the key factor for productivity and persistence

Soil tillage

Soil tillage aims at obtaining a soft seed bed in the first 20 cm to facilitate root growth and nodulation and to incorporate fertilizers. Phosphorous (P_2O_5 , 50-60 kg ha^{-1}) and potassium (K_2O , 100-120 kg ha^{-1}) fertilization is recommended and a small amount of nitrogen (20-30 kg ha^{-1}) during soil tillage can be useful to feed the seedlings after emergence facilitating the establishment while the symbiosis is not working yet. Seed-to-soil contact is crucial. Seed coating or pelletizing favors soil adhesion to seeds and improves seed moisture uptake. A fine seed bed is especially required in heavy soils, to guarantee high and prompt seed germination. In all soils, the sowing depth must not exceed 1.5 cm.

Sowing season

In mild-winter Mediterranean environments, sowing is usually carried out in early autumn or in early spring (mid-March). Seedlings have thus time to set up a well-developed rooting system before the onset of winter and to withstand low temperatures or to take advantage of the rising diurnal and nocturnal temperatures and the lengthening of days in spring.



Figure 3. Lucerne establishment

Seed rate in pure stand

Seed rates can range from 25 up to 40 kg ha⁻¹ depending on variety, soil type, seed treatments (raw or coated seeds) and type of stand utilization. The optimal number of established plants ranges between

200 and 400 m⁻². Higher rates are for hay production in moisture-favorable environments, or for sowing in soils with poor seed bed quality. Lower rates are appropriate for hay production in low-rain areas, or with grazing-type varieties.

Mixtures

Lucerne can be grown in pure stand or in mixtures with grasses. Mixtures are mainly used in farming systems where grazing is carried out but they can also be used for mowing. Mixtures have the potential to:

- ✓ Increase total pasture production and extend the grazing season
- ✓ Provide greater resilience in variable seasons
- ✓ Reduce bloat risk in ruminants compared to lucerne pure stands
- ✓ Provide a well-balanced forage in protein and energy



Figure 4. Lucerne-grass mixture

Suitable mixtures are based on summer-dormant or drought-tolerant varieties of perennial grasses such as tall fescue (*Festuca arundinacea*) and cocksfoot (*Dactylis*

glomerata). Commonly used seed rates in mixtures are 10-20 kg ha⁻¹ in a mixed sward with 15-20 kg ha⁻¹ of perennial grasses.

Crop management

Weed control

Chemical treatments are not needed, with the possible exception of the establishment year. In case of weed infestation, one cleaning cut made before weeds set seeds should be sufficient to cleanse the stand. Weed control is easier with mixture because the soil is always covered and the plants generate severe competition to weeds.

Maintenance fertilization

When well developed, lucerne does not require further fertilization. Fertilization is only required to enhance seed production in specialized crops.

Irrigation management

Lucerne is tolerant to water deficit but it reaches higher production under irrigation. Its water requirements are around 13-14000 m³ per hectare in Mediterranean drought-prone environments. In these environments, irrigation can be applied along the entire growing season. Although lucerne maximum water requirements are registered during flowering, it is advisable to irrigate the crop after forage harvesting, in order to cut herbage that dries quickly after harvest and to boost lucerne growth after harvesting. Flood irrigation can be used for lucerne, but spray irrigation should be preferred especially in sandy soils. Water volumes to be distributed depend strongly on soil characteristics and environmental conditions. On average, 300-500 m³ per hectare are required at each irrigation.

Forage harvest and grazing time

Under irrigation, lucerne is among the highest yielding forage legumes: up to 25-28 t year⁻¹ in the first and second year, 8-15 t year⁻¹ in the third year from sowing. In less favourable conditions, lucerne yield is lower. In Morocco, the average production is 5.93 t DM ha⁻¹ and in Algeria 3-4 t DM ha⁻¹.



Figure 5. Sheep grazing on lucerne stand

Optimal time for use (cutting for hay or grazing) is at beginning of flowering (1st cut) or after 4-8 weeks from the previous mowing/grazing cycle. Sufficient regrowth must be ensured before further utilization, to favour the replenishment of underground reserves and avoid excessive plant

mortality. Rotational grazing should be preferably carried out to improve stand persistence. Under continuous grazing, lucerne persistence is poor, except for specifically-selected varieties.

Forage conservation

Several options are possible:

- Hay
- Dehydrated forage
- Silage

The methods of conservation can influence the forage nutritive value because of possible losses of plant parts or forage compounds during the conservation processes.

For instance, crude protein content is higher in ensiled lucerne than in hay, where high amounts of leaves might be lost during hay-making.

Quality of lucerne forage

Lucerne forage is very palatable, has high protein content, a fiber content that helps rumination, a buffering pH effect that limits the risk of acidosis, and is highly digestible (60-75% of total DM). It contains high levels of Net Energy (8-11 MJ kg⁻¹ DM). Problems for animals fed with lucerne are rather limited. Possible disorders in ruminants such as bloat or red gut can be conveniently minimized by avoiding grazing young/lush lucerne stands, especially by hungry stock. In that case, pre-feeding with dry roughage is recommended.

Table 3. Qualitative parameters of lucerne in pure stand and in mixture with grasses and comparison with quality parameters of grasses in pure stand. Modified from Davolio *et al.*, 2012.

	Lucerne pure stand			Lucerne mixtures			Grasses pure stand		
Parameter	avg	min	max	avg	min	max	avg	min	max
Protein	18.0	10.8	26.9	12.3	8.2	18.2	9.5	5.0	18.5
NDF	43.3	30.4	58.2	50.5	37.1	66.4	54.7	39.1	68.8
ADF	35.3	23.5	44.7	37.2	27.7	44.2	36.9	24.9	45.1
ADL	7.9	5.4	10.2	6.8	2.7	9.8	5.4	2.7	9.2
Ash	10.6	7.4	17.3	9.3	7.6	11.3	8.7	5.0	14.8
Starch	1.7	0.5	3.1	2.1	1.0	3.0	1.9	0.6	3.7
Sugars	6.8	2.2	10.8	8.3	4.4	14.7	9.9	5.0	18.0

Plant diseases and pests

Several pests can be harmful to lucerne. For forage production, only nematodes (*Ditylenchus dipsaci*, *Meloidogyne halpa*, *Pratylenchus*



Figure 6. A green and healthy lucerne crop in Gabes Oases (South Tunisia). Year 2014.

spp.), sitona (*Sitona humeralis*, *S. discoideus*) and aphids may cause problems. Other pests may be detrimental to seed production.

Among the major diseases are Verticillium wilt (*Verticillium albo-atrum*), stem rot (*Sclerotinia trifoliorum*), *Pseudopeziza medicaginis*, lucerne anthracnose (*Colletotrichum trifolii*), lucerne rust (*Uromyces medicaginis-orbicularis*), *Peronospora trifoliorum* and violet root rot (*Rhizoctonia violacea*).

Some parasitic plants are also

harmful to lucerne: dodder (*Cuscuta campestris*) and broomrape (*Orobanche minor*).

Viroses are of little importance in lucerne.

OUTCOMES OF THE PROJECT REFORMA

The Project REFORMA 'Resilient, water- and energy-Efficient FORage and feed crops for Mediterranean Agricultural systems' is an EU-funded project that started in 2012. It ended in December 2016. The overall aim of the project was strengthening the economic and environmental sustainability of Mediterranean crop-livestock and feed systems, also by enhancing their self-sufficiency for feed proteins and their ability to adapt to and to mitigate climate change. This was pursued by developing more resilient and more water- and energy-efficient systems based on genetically-improved forage and feed legume species. Among other specific aims, the project REFORMA aimed at: (i) optimizing the cultivation of lucerne under rainfed conditions with no irrigation and its use in pure stand or in association with tall fescue or cocksfoot; and (ii) at comparing perennial mixtures in terms of acceptability by farmers, defining the agricultural contexts in which each mixture may be preferred.

Two sites were involved: Sassari (Italy) and Marchouch (Morocco).

The experiment

The following species and varieties were used: lucerne, erect type 'Surigheddu' (L1); lucerne, semi-erect type 'Bulk' (L2); cocksfoot cultivar Kasbah, summer dormant (C); tall fescue cultivar 'Flecha' (F). This materials were cultivated under rainfed conditions in pure stands (L1, L2, C, F), in binary mixtures (L1F, L1C, L2F, L2C) and complex mixture (L1L2FC).



Figure 7. Lucerne 'Surigheddu' (on the left) and lucerne 'Bulk' (on the right).

Plot size: 4 x 3 m

Fertilization of grasses in pure stand

- In the first year: 30 kg ha⁻¹ of N and 135 kg ha⁻¹ of P₂O₅ incorporated in the soil during soil tillage + 30 kg ha⁻¹ of N at the end of winter
- In the subsequent years: 30 kg of N distributed at the end of winter

Fertilization of legumes in pure stands and in grass-legumes mixtures

- In the first year: 15 kg ha⁻¹ of N and 135 kg ha⁻¹ of P₂O₅ incorporated in the soil during soil tillage + 15 kg ha⁻¹ of N at the end of winter
- In the subsequent years: 15 kg of N distributed at the end of winter

Seeding date: November 2013.

Seed rates: 25 kg ha⁻¹ for legumes and 30 kg ha⁻¹ for grasses in pure stands. The seed rates were halved in binary mixtures and reduced to one fourth in the complex mixture.

Irrigation: not applied. Plots were entirely rainfed.

Harvests: 11 cuts in Italy, 5 cuts in Morocco between 2014 and 2016

Dry matter yield and weed proportion were determined in each cut.

Table 4. Dry matter yield (t ha⁻¹) harvested in each cut in Sardinia (Italy) from 2014 to 2016.

<i>Harvest date</i>											
Crop	<i>2014</i>	<i>2015</i>							<i>2016</i>		
	<i>19 Sep</i>	<i>7 Jan</i>	<i>26 Mar</i>	<i>3 Jun</i>	<i>6 Jul</i>	<i>4 Aug</i>	<i>3 Sep</i>	<i>28 Dec</i>	<i>11 Apr</i>	<i>6 Jun</i>	<i>8 Aug</i>
L1	1.0	0.4	0.5	6.2	2.1	0.8	0.4	1.2	0.7	1.3	0.7
L2	0.4	0.2	0.3	4.2	1.4	0.7	0.3	1.0	0.8	0.9	0.3
C	0	0.9	0.5	0.8	0	0	0	2.8	0.8	0.1	0
F	0	0.8	1.0	2.6	0	0	0	3.8	1.0	0.6	0
L1C	0.7	0.7	0.8	4.9	1.7	1.0	0.4	2.7	1.3	1.1	0.4
L1F	0.6	0.7	1.0	5.0	1.5	1.2	0.4	3.3	1.4	1.3	0.6
L2C	0.2	0.8	0.5	2.8	1.2	0.5	0.2	2.7	1.5	1.0	0.3
L2F	0.2	0.7	1.0	3.4	0.6	0.2	0.2	2.1	1.3	1.3	0.2
L1L2CF	0.5	0.7	0.9	4.3	1.3	0.8	0.4	2.8	1.6	1.3	0.5

Table 5. Dry matter yields (t ha⁻¹) harvested in each cut in Morocco from 2014 to 2016

Crop	Harvest date				
	2014	2015		2016	
	16 May	22 Apr	10 May	3 May	2 Aug
L1	1.9	8.2	3.0	3.8	4.3
L2	1.3	6.0	2.1	2.0	2.8
C	3.0	4.1	0.0	1.3	0.0
F	2.8	4.3	0.0	1.0	0.0
L1C	1.6	6.6	2.9	3.3	3.5
L1F	1.7	7.5	2.4	3.4	4.2
L2C	1.7	7.1	1.0	2.1	1.5
L2F	2.7	7.2	0.8	1.6	1.5
L1L2CF	2.6	9.0	2.6	3.0	3.0

In Morocco, DM production was concentrated in spring, and crops yielded higher DM than in Italy. Nonetheless, in Italy crops produced throughout the year.

L1 performed better than L2 in both sites and showed a better weed control. F performed better than C in Italy. The mixtures containing L1 and F showed the best productive results.



Figure 8. Lucerne and grass experiment in Sassari, Italy (March 2014)



Figure 9. Perennial species in Marchouch, Morocco (April 2015)

Summarizing the results, we concluded that: (i) the erect type of lucerne had better productive performance than the semi-erect type in both experimental sites; (ii) tall fescue was the best choice to be used in binary mixtures with lucerne; and (iii) the four-component mixture was as good yielding as the best lucerne pure stand or binary mixture.

An important and innovative approach of REFORMA Project was the involvement of farmers in the crop evaluation. Farmers were invited once a year to assign a visual score to crops estimating their productive level, their suitability for introduction into the existing farming systems and their usefulness as feed resources.

There was good correspondence between the farmers' visual score and the forage yield level of crops. For example, in Italy, L1 score > L2 score, and F score > C score among monocultures reflected the higher DM yield of L1 and F compared to L2 and C, respectively. In analogy, L1- and F-based mixtures received higher scores than L2- and C-based mixtures.



Figure 10. Farmers' assessment during the field days in Marchouch (Morocco) and Sassari (Italy).

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