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Alfalfa (*Medicago sativa* L.) management for irrigated Mediterranean conditions: The case of the Ebro Valley

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SUMMARY – The Ebro Valley is the main alfalfa producing area of Spain, with more than 80% of the irrigated national production. This paper reviews the management practices followed in the area, with the technical knowledge that supports the decisions (varieties, water use, seed rates, seeding time, fertilization, slurry application, harvest frequency, cutting height, weed and insect control, grazing and hay production). However, although alfalfa is a traditional crop in the irrigated areas of the Ebro Valley, there are few publications about management recommendations, and for this reason many practices are based on many years of farmer's experience or on publications from other areas.

Key words: Varieties, seeding rates, grazing, harvest frequency, fertilization.

RESUME – *"La culture de la luzerne (*Medicago sativa *L.) irriguée dans la région méditerranéenne : Le cas de la Vallée de l'Ebre". La Vallée de l'Ebre est la principale région productive de luzerne en Espagne avec plus de 80% de la production irriguée nationale. Cette étude constitue une révision des plus importantes techniques de culture appliquées dans cette région avec la connaissance technique qui soutient les décisions (variétés, utilisation hydrique, dose de semis, temps d'ensemencement, fertilisation, application de purin, fréquence de coupe, hauteur de coupe, mauvaises herbes et lutte contre les insectes, pâturage et séchage du foin). Cependant, bien que la luzerne constitue un produit traditionnel dans la zone de la Vallée de l'Ebre, il y a peu de publications sur les recommandations pour sa culture. Pour cette raison, beaucoup de pratiques sont basées sur l'expérience des agriculteurs ou sur des publications d'autres cultures.*

Mots-clés : *Variétés, dose de semis, pâturage, fréquence de coupe, fertilisation.*

Introduction

The production of alfalfa in irrigated Mediterranean areas, where it is a traditional crop, is characterized by a summer water deficit, long growing seasons and intensive production systems (Del Pozo and Ibañez, 1984; Dovrat, 1993).

In Spain, alfalfa is grown in about 237,000 ha, 75% of which are under irrigation. Of this area, about 80% (130,000 ha) is located in the Ebro Valley where it is primary dehydrated and exported to other areas (Ollé, this volume). For this reason, a review on the alfalfa management practices in the Mediterranean areas of Spain should be mainly dedicated to this Valley.

Even though alfalfa is a traditional crop in the irrigated areas of the Ebro Valley, there are few research publications about management techniques of this crop. Many of the management recommendations are based on the farmer's experience over years or on publications from other areas (Hidalgo, 1969b; Hycka, 1982; Le Gall *et al*., 1992; Mauries, 1994).

The objective of this paper is to summarize the most common alfalfa management practices followed in the irrigated Mediterranean conditions of the Ebro Valley. This review will include the key factors for optimizing alfalfa production in irrigated areas that should include (Marble, 1989): varieties, soil depth, water needs, seeding methods, fertilizer recommendations, harvest management, diseases, insect and weed control and forage drying.

Varieties

In the Mediterranean areas of Spain several ecotypes have been described: Alcoroches, Ampurdán, Aragón, Mediterránea and Tierra de Campos (Hidalgo, 1969c). However, at present, the most important ecotypes and varieties grown are Aragón or Aragón derived, such as Victoria, Capitana and Baraka, with more than 80% of the national market (INIA, pers. comm.). Although these varieties are the most widely cultivated, in recent years seed companies have been introducing foreign varieties of dormancy ratings of 7 and 8, mainly of USA and Australia origin.

Yield trials comparing traditional with recent introductions have been conducted on a limited scale. In several trials, some recently introduced foreign varieties outyielded Aragón, mainly in areas with heavy nematode infection. This difference in yield may be due to the flooding irrigation systems used to grow alfalfa (Lloveras *et al*., 1999).

A series of field trials showed that Ampurdán, Baraka and Capitana, were the best alfalfa varieties among the traditional ones. Whereas GT R13Plus, 13R Supreme and Artal, of USA origin, showed to be the best adapted of the recent alfalfa introductions. The average dry matter (DM) yields of the best varieties were of between 21 and 23 t/ha (Lloveras *et al*., 1999).

The type of irrigation may have influenced forage yields. The yield results obtained under sprinkler irrigated conditions may differ from those obtained with flood irrigation.

Soil depth

High yields of alfalfa are obtained from soils free of hardpan, with a minimum of 1.0 to 1.5 m of rooting depth (Marble, 1989). However, in the Ebro Valley soil depths are normally limited reducing the water holding capacity (Boixadera *et al*., 2001). In these conditions, Hidalgo (1969b) found a significant correlation between soil depth and DM yield. He showed a 5% increase in DM yield for each 10% increase in soil depth, on soils whose depth was between 30 and 70 cm.

In some areas salinity is limiting the production of alfalfa (Arrojo and Bernal, 1997; Boixadera *et al*., 2001). The same phenomenon has been also observed in other Mediterranean countries (Mezni *et al*., 1999).

Water

Alfalfa has a relatively high water demand because of the long production season and frequent harvesting (Guitjens, 1990).

In the Ebro Valley and central Spain, where the average precipitation is about 400 mm/year, irrigation is needed to obtain high forage yields. Two main irrigation systems are used: flood and sprinkler irrigation (Hycka, 1982; Masip and Fraile, 1999).

Orientative data shows that the water consumption by alfalfa in the Ebro Valley is about 11,000 m^3/ha (Faci, 1984), and the water supplied by irrigation is between 600 and 1000 mm per season. This water consumption can vary within the area.

This high consumption of water has been questioned, because water is considered a limited resource. As a consequence there is a media pressure for a better water management (Caballero, 1999).

Sowing

In Mediterranean conditions, with relatively mild winters, alfalfa can be sown in the spring or autumn of the year. In the Ebro Valley, most of the fields are usually sown in the spring, with the objective of reducing winter frost damage and weed contents of the first harvest. However, in recent years dehydration companies prefer autumn sowing in order to obtain higher yields in the first year of production (Lloveras, 1999).

Field trials show that although autumn sowing favours highest DM yields in the first year, giving maximum first year yields equivalent to those of a second year stand, the total DM yields of spring and autumn sowing is similar in a three year average (Lloveras *et al*., 1999) (Table 1).

Table 1. Average dry matter yield (t/ha) of alfalfa over time (Lloveras *et al.,* 1999)

Sowing time	First year	Second year	Third year	Average
Spring (6 trials)	16.1	26.0	21.4	21.2
Autumn (3 trials)	24.5	21.9	18.3	21.5

Sowing rate

Sowing rate is another production factor to considerer in alfalfa management.

In flood irrigation systems, many alfalfa growers of the Ebro Valley use between 30 to 40 kg/ha of seed, with a row width of about 15 cm. This practice yields a nice looking crop after sowing. Companion crops are not normally used.

Many growers do not mind using high sowing rates. This is because the cost of the seed might not be an important production component to consider in a crop that is sown once every four or five years. However, for large landowners seed density is becoming an important economic factor.

Santiveri *et al*. (1999) showed that, in well-prepared land, seed rates could be reduced, at least, down to 10 kg/ha (Table 2). Similar recommendations have been reported by Bessac (1967) in France and Bonciarelli (1987) in Italy. However, in areas with rocky soils, it is difficult to obtain a uniform sowing and probably 20 kg/ha should be recommended to avoid week stands (Roselló and Hidalgo, 1981; Hycka, 1982).

Table 2. Effect of sowing rate of alfalfa on the number of plants, number of stems, dry matter (DM) yield and crude protein (CP) contents. Average of Aragón and Artal in Gimenells (Santiveri *et al.,* 1999)

Seed rate (kg/ha)	Plants/m^2		1998		
	Initial 1998	Spring 1999	No. of stems/m^2	DM yield (t/ha)	CP (%)
10	155 a	110 a	492 b	20.5 a	20.49
20	204 b	193 b	505 a	20.7 a	20.68
30	330 c	265 c	513 a	20.7 a	20.66
40	322 c	205 b	526 a	20.4 a	20.38

[a,b,c]Numbers with the same letter are not significant different at $P < 0.05$.

Seed density may also vary depending on the type of irrigation. Sprinkler irrigation when compared with flood irrigation reduces surface crusting, especially in spring sowing. Robinson *et al*. (1968) reported that the use of sprinkler irrigation to germinate alfalfa has proven superior to flood irrigation.

Inoculation

Inoculation is not normally used, and no yield increase has been observed with inoculation in soils were alfalfa has been traditionally grown (Hidalgo, 1969b).

Fertility

Alfalfa is a high yielding, high quality perennial forage that removes plant nutrients from soil in large quantities. For optimal production, the nutrients must be available at the appropriate level and time (Lanyon and Griffith, 1988).

Although fertilization is an important production factor, there is little research available from Mediterranean areas and present recommendations are normally based on the amounts removed by the crop (Hidalgo, 1969a; Bonciarelli, 1987; Le Gall *et al.,* 1992).

In the Ebro Valley, alfalfa is part of the rotation alfalfa-maize-wheat, that has been followed for many years. Because maize and wheat have been heavily fertilized, P and K soil test levels are normally high in this valley. In general, the soil test levels found in the alfalfa growing areas of Spain varied greatly, but in the Ebro Valley they are of the order of 37-45 ppm of P and 165-185 ppm of K (LAF, 2000).

A survey conducted in Aragón Community has shown that the current fertilizer applications by alfalfa growers are of the order of 45 kg/ha of N, 60 kg/ha of P and 86 kg/ha of K (Ruiz *et al*., 1993). A more recent survey sent to the alfalfa dehydrators showed annual applications of 35-90 kg/ha of N, 35-40 kg/ha of P and 150- 250 kg/ha of K (Lloveras, 1999). They often conduct soil test analysis before sowing.

Nitrogen

Fertilizing established alfalfa stands with N is a practice generally questioned especially if the plants are properly nodulated. There is little data available to support or contradict the use of this practice of fertilizing nodulated alfalfa (Hannaway and Shuler, 1993).

In the Ebro Valley, however, several dehydrators apply N by the end of winter with the objective of increasing DM yields in the first harvest. They do this because they are concerned that cold spring temperatures might reduce spring regrowth (Lloveras *et al.,* 2000). However, preliminary results suggest that this type of fertilization increases DM yields primarily because of the increase in weed content (Table 3).

Table 3. N fertilization effects on dry matter production (DM), crude protein (CP) and weed contents in Palau de Anglesola, 1998 (Lloveras *et al.,* 2000).

N treatment (kg N/ha/year)	1st harvest			2nd harvest	
	DM yield (t/ha)	CP (%)	Weeds (%)	DM yield (t/ha)	CP (%)
0	2.77	20.28	32.1	4.13	23.30
30	3.52	19.80	43.6	3.87	23.86
Average	3.14	20.04	39.9	4.00	23.58
Significance	0.05	NS	0.01	NS	NS
CV (%)	15.6	4.5	25.0	8.3	6.7

Phosphorus

The average recommendations are of the order of 80 kg/ha of P (Hycka, 1982; Bonciarelli, 1987; Le Gal *et al*., 1992).

The most extended work on P fertilization in the Ebro Valley was conducted by Hidalgo (1969a). Hidalgo (1969a) found initial DM increases with the addition of P, although latter applications did not affect the DM yields. Soil P contents increased with the application of P. Lorenzo and Labayen (1973) found in soils with low P contents, that a 27% DM yield increase occurred from 54 t/ha to 69 t/ha, with the application of 40 kg/ha of P.

Potassium

The K requirement of alfalfa is usually considered the most important limiting nutrient (Lanyon and Griffith, 1988).

Results from the most successful high-yield alfalfa research and producer fields reflects a degree of luxury consumption for K and that all K removed was not essential for plant growth (Marble, 1989).

In the Mediterranean areas of southern Europe, although the research is limited, present recommendations based on the amounts of K removed by the crop are between 200 and 350 kg/ha/year of K (Hidalgo, 1969a; Le Gall *et al*., 1992).

Lloveras *et al.* (2001) studied, in the Ebro valley, the use of K in soils with high initial levels of K, and found a small linear response with the use of K. The average annual DM yield was 21.5 t/ha and showed a 3.4% increase for the highest rate of K used. No significant yield differences were found when comparing similar amounts of K applied annually (41.5 and 83 kg/ha/year of K) or the same four-year quantity at seeding (166 and 332 kg/ha of K).

On the other hand the heavy removal of K did not compensate for the amounts of K applied, reaching a four-year total of 1546 to 1728 kg/ha of K with the application of 0 or 332 kg/ha/year of K.

Despite the uptake of 1546 kg/ha of K in the control plots and similar amounts in other treatments, soil K exchangeable values did not change appreciably during the study. This suggests that much of the K uptake was derived from the fertilizer and from non-exchangeable soil K fractions.

Although K fertilization slightly increased alfalfa DM yields in this Mediterranean high K testing soil, the economic benefit of this limited response does not justify the expense.

Higher responses to K were reported by Kafkafi *et al.* (1977), in irrigated eastern Mediterranean conditions. In this area yields were raised from 15.2 t/ha with 0 K to 20.9 t/ha DM with applications of 316 kg/ha of K in a soil with initial K values of about 180 mg/kg of K.

Secondary nutrients

Boron deficiencies have been observed in several fields, and some dehydrators usually apply B annually, even though its effect on forage production is difficult to measure. Hidalgo (1969a) did not find a DM yield increase with the application of B and Mg.

The effect of B applications on alfalfa seed production was also studied over several years, without showing any seed yield increase (Martínez, 1993).

Slurry manure management

Because the Ebro Valley is an important pig production area, the application of slurry manure on alfalfa is a common practice. However, little data is available on the effects of the slurry manure on alfalfa.

The general knowledge is that even if the soil is well provided, slurry manure might increase DM yields due to an increase in the weed proportion of the forage. This may occur at least in the first cutting, because weeds can take better advantage of the N of the slurry (Schmitt *et al.,* 1991; Kelling and Schmitt, 1996).

In the Ebro Valley, Mangado and Ameztoy (1997) compared the effects of mineral fertilization with one application of slurry manure (25 m^3/ha) on the production of alfalfa, in soils well provided of P and K. They did not find differences in the forage DM yield, obtaining 20.5 t/ha and 20.0 t/ha DM, by the use of mineral fertilization or fertilization with slurry, respectively. They did not observe any detrimental effects of the slurry to the crop. The transportation and the application of slurry manure was more expensive than that of mineral fertilizer.

Some dehydration factories observed a darker color and a quality reduction of the alfalfa stands where slurry was applied after each cutting (David Torrent, pers. comm.)

Harvest frequency

Alfalfa growers are under increasing pressure from the feed and dehydration industry to increase forage quality. This trend is modifying the traditional harvest management systems of the Ebro Valley, causing an increase of harvest frequency (Lloveras *et al*., 1998).

The association of forage quality increase with decreasing yields is well documented (Undersander *et al*., 1991; Mauries, 1994; Ligabue and Tabaglio, 1996). Local research is needed to quantify the effects of harvesting under particular growing conditions. In Spain, the effects of harvest management on alfalfa production and quality have been studied by Hidalgo (1969b), Arevalillo *et al*. (1973) and Lloveras *et al*. (1998).

As a consequence of increasing harvest frequency, the average number of cuttings in the Ebro Valley, has increased from five to six. In southern Spain, however, with a longer growing season, and using varieties such as Mediterránea, Guilboa and Imperial 70, alfalfa can be harvested up to 10 times per season (Olea *et al*., 1981).

In the Ebro Valley, alfalfa is usually harvested at flowering. Research shows that advancing harvest to late bud-first flower increased harvest frequency and forage quality in comparison with full bloom cuttings. CP contents increased by 8.2% from 16.6 to 21.2% and *in vitro* digestibility (IVDMD) by 5.7% from 69.8% to 73.8%, whereas DM yield decreased by 18% (25.5 vs. 21.6 t/ha). At the same time, cutting stage significantly affected autumn forage production and quality and first spring cut yields. Full bloom harvests allowed better autumn and spring regrowth than late bud cuttings, probably due to higher root reserve accumulation during the mid-season harvests (Lloveras *et al*., 1998).

Autumn harvest management

The importance of proper autumn management for yield and persistence of alfalfa have been studied in areas of cold winters. Alfalfa harvested in these areas after the "critical fall harvest period", the period of 4 to 6 weeks prior to the first killing frost, can result in winter injury and can be detrimental to the following spring and growing season yield (Mays and Evans, 1973; Sheaffer *et al*., 1986).

However, in mild winter climates some reports suggest that fall or winter alfalfa harvests might have little significance on the yields of following year (Hidalgo, 1969b; Marble *et al*., 1989).

In our climatic conditions, autumn harvests influenced first spring cut. Cuttings before the first frost in fall reduced vigour and first-cut alfalfa in comparison with harvests taken after or near the first fall frost. However, their effects were observed only in the yields of the subsequent first spring cut, but not in the total annual production (Lloveras *et al*., 1998).

Cutting height

Height of cutting does not appear to be an important factor in the Ebro Valley, and it seems that it does not affect the persistence of the crop under the recommended cutting frequencies.

However, Hidalgo (1969b) found that cutting at 5 cm reduced DM yields compared with heights lower than 3 cm, whereas, Luna and Delgado (1994) observed, in pot trials, fastest regrowth with cuttings at 10 cm of height compared with 1, 3 and 5 cm when alfalfa was harvested at 50% flowering.

At present, tall stubble may be needed by the dehydration industry to obtain a cleaner crop.

Weed control

In many Mediterranean countries alfalfa is considered a clean crop that leaves the fields clean for the next crop. Weeds do show up frequently in alfalfa after the third year (Marchiol *et al.,* 1996). The most important weeds and recommended herbicides for alfalfa in the Ebro Valley have been reported by Zaragoza and García (1984).

Weed infestations have been observed mainly in the first year, and in the first spring harvest, reducing DM yields and quality, although their real effect has not been quantified. However, the price penalty for a weedy crop is pushing growers towards the application of herbicides by the end of winter. Hexazinona and paraquat are the most frequently applied herbicides to alfalfa (Ruiz *et al.,* 1993; Lloveras, 1999).

Insect control

The main insects observed in the Ebro Valley are *Apion pisi*, *Phytonomus variabilis*, *Colaspiderma atrum* (García and Sanagustín, 1984), and three species of aphids *Aphis craccivora*, *Acyrthosiphon pisum* and *Therioaphis trifolii* (Pons and Lloveras, 1999).

In a normal year the crop receives one or two insecticide sprays primarily on the first harvest. In difficult years the number of sprays can increase up to four or five. At present, 100% of the farmers use insecticides (Ruiz *et al.,* 1993).

A survey of the most frequent insecticides used to control insects are: carbaryl, endosulfan, fenvalerate, fenitrothion+fenvalerate, for *apion* and *Phytomus variabilis*; carbaryl, cipermethrin, clorpiriphos, deltamethrin, fenitrothion, esfenvalerate, malathion, methilchloryriphos for *Colaspiderma atrum;* and malathion, fenitrothion, clorpiriphos and endosulfan for aphids (Lloveras, 1999).

Diseases

Verticillium and *Fusarium* wilts and *Phytophthora* root rot, are common diseases in the irrigated areas of the Ebro Valley (García and Sanagustín, 1984; Raynal, 1986), but growers are little aware of their effects. However, in flooding irrigated conditions stem nematode (*Ditylenchus dipsaci*) seems to be the most detrimental disease (Lloveras *et al*., 1994). In sprinkler irrigated systems, nematode effects have not been clearly observed and *Verticillium* might become more common.

Vertebrate "pests"

Rodents such as moles (*Pitymus duodedimicostatus*) are becoming important "pests", damaging the alfalfa fields, mainly in sprinkler irrigation systems. This may be due to the reduction of their natural enemies such as snakes, birds, etc. Their damage is reduced in flood-irrigated conditions, probably because of drowning.

Harvesting equipment

Any discussion of alfalfa is incomplete without a caution on the perils of compaction. Compaction reduces the amount of water and air available for the alfalfa root growth and development, and can increase crown injury and as a consequence reduces yields (Anderson, 1998).

In recent years, alfalfa growers of the Ebro Valley have been noticing a reduction in crop persistence. This decrease might be due to an increase soil compaction because of heavier harvesting equipment, increase harvesting and irrigation frequency.

Pasture

Alfalfa is not widely used for grazing in the Ebro Valley. Growers are normally afraid to graze the crop because of the possible yield, stand reduction and of the danger of animal bloat (Delgado, 1984).

Delgado (1993), however, reported a DM yield decrease of only 6.3% when comparing grazing vs. hay production with a 30 day recovery period. He concluded that with the appropriate delay between grazing periods, alfalfa can also be used for grazing in the Ebro Valley.

Winter pasture

Most of the alfalfa grown in the Ebro Valley is for dehydration and hay. However, during the winter when the crop is "dormant" or the growth is reduced; alfalfa is pastured by sheep (Monserrat and Fillat, 1990).

During the winter, sheep graze on the autumn regrowth or the autumn leftovers of alfalfa. There is a controversy about this practice. Farmers believe that winter grazing causes a DM yield reduction in the following spring, whereas sheep owners believe that is beneficial for the crop.

Preliminary results show that both opinions are correct, because when alfalfa is grazed once during the winter, there is a small yield reduction of the first spring harvest, with an increase in the quality of the forage because of the lower proportion of weeds (Fanlo *et al.,* 1999) (Table 4).

Table 4. Effect of the winter grazing on dry matter (DM) yield and crude protein and weed contents of the first spring harvest in Gimenells, 1998-2000 (Fanlo *et al.,* 1999)

Treatment	DM yield (kg/ha)	Alfalfa (%)	Weeds (%)	Crude protein (%)
Grazed	2894	7.2	41.3	17.4
No grazed	3111	49.9	47.1	19.6

Research conducted in New Zealand (Wynn-Williams *et al*., 1991) and USA (Pelton *et al*., 1988), also observed that winter pasture favors insect control, reducing the number of pest in spring.

Last winter, alfalfa hay producers avoided winter pasture, because they tried to eliminate any risk of possible infection by Foot and Mouth disease virus (Aphtous fever).

Hay production management

It is well known that the hay making process produces DM and quality losses (Dulphy, 1987).

Preliminary results from the Ebro Valley shows that when alfalfa is harvested at 30% humidity, as required by the EU in order to obtain the subsidies to the dehydration, the DM and CP losses are of the order of 13.8 to 19.4% and of 6.5 to 7%, respectively (Jounou *et al.,* submitted for publication) (Table 5).

As a consequence, it can be concluded that harvesting alfalfa at 30% humidity, which requires about two to three days of normal field drying in the Mediterranean conditions, seems a good management system. However, the losses could be much higher if the forage was weathered by rain.

Research required

Although alfalfa is a traditional and important crop in the Mediterranean areas of Spain, there is still an important lack of knowledge about the quantification of the effects of management practices on crop yield and quality. Today, where the effects on the environment may be more important than yields, future research would have to study the effects of alfalfa management practices in the environment.

Under our irrigated conditions, the increased efficiency in the use of water and fertilizers, the more appropriate insect control, pasture management, and the effects of alfalfa in the crop rotation together with the application of slurry manure, are aspects of the crop management that should be studied.

Table 5. Dry matter production (DM) per harvest, leaf/stem ratio (LSR), crude protein (CP) contents, hay making losses and dry matter contents at two methods of harvesting in Gimenells,1999 and 2000 (Jounou *et al.,* submitted)

Harvesting stage	Type of harvest	DM (t/ha)	LSR (g/g)	CP (%)	DM at harvest (%)
Bud stage	MH[†]	2.94	1.05	23.60	21.3
	FD[††]	2.52	1.07	22.03	69.0
	Losses (%)	13.8	2	6.5	–
	Significance	*	N S	**	–
Full bloom	MH	3.75	0.85	20.80	22.3
	FD	3.05	0.70	19.35	68.7
	Losses (%)	19.4	6	7.0	–
	Significance	**	*	*	–

[†]Machine harvested, directly form the field.
[††]Field dried hay.
*P < 0.05, **P < 0.01, NS = non-significant.

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