Significance of phosphorus fertilizer for annual Medicago spp. in semi-arid Morocco

Derkaoui([1]), M., J. Ryan([2]), and M. Abdel Monem([2])
[1] *Aridoculture Center, P.O. Box 589, Settat, Morocco*
[2] *International Center for Agricultural Research in the Dry Areas (ICARDA), P. O. Box 5466, Aleppo, Syria.*

ملخص

الفصة السنوية نوع من البقوليات الشهية و ذات قيمة غذائية عالية. وتمكن من تثبيت الآزوت كما تمكن التجديد الذاتي.
يمكن للفصة أن تلعب دورا هاما داخل أنظمة انتاج زراعة الحبوب و تربية الماشية كما هو الشأن بالنسبة للمناطق الجافة وشبه الجافة بالمغرب.
لقد شكلت الدراسات التي أنجزت حول هذ ه الاصناف الكلئية عنصرا هاما في إطار الابحاث التي أجريت بمركز الزراعة الجافة بسطات. وبالرغم من كون الفوسفور يشكل عنصرا هاما بالنسبة للكتلة الحيوية و الجودة، ، ونشير الى أنه بالمغرب هناك دراسات قليلة انجزت حول استجابة الفصة للتلطيف بواسطة العناصر التكميلية في التربة التي تعاني من نقص في الفوسفور.
استعمال الفوسفور من طرف جميع اصناف ميديكاكو لم توضح لحد الآن. لقد تمت إقامة تجارب في أوعية على فرتيسول في مستوى أدنى من الفوسفور مخصب بمستوى 100,50,0, 200 ppm من الفوسفات باستعمال ثمانية أصناف وراثية. في نفس الاطار ثلاث أصناف منتخبة تم زرعها في الحقل في تربة palexeroll petrocalcique ذات عمق ضعيف تحتوي على كمية ضعيفة من الفوسفور مع اضافة كميات من الفوسفور تتراوح ما بين 15٠0 و30 و60 كلغ من الفوسفور.
في البيوت الزجاجية ، جميع اصناف الفصة مع تغيير بين الاصناف الوراثية أسفرت عن نتائج إيجابة تتمثل في زيادة انتاج الكتلة الحيوية ومع ذلك عندما تتجاوز نسبة زيادة الفوسفور pm50 لاتحدث أية استجابة مع ملاحظة بعض التقلص في الانتاج عند إضافة pm200 . من جهة ثانية ، فإن امتصاص الانسجة للفوسفور عرف ارتفاعا مع ارتفاع مستوى إضافته . في الحقل، فإن الاصناف sava و serena أبانت عن استجابة عالية . مردودية serena كانت ضئيلة ، كما أن نموها لم يكن جيدا .
نتسنتج أنه بالنسبة للتربة الذي تعرف نقصا في الفوسفور أي أقل من pm7 ، فإن إضافة الاسمدة الفوسفورية والرزيبوم يعد ضروريا للحصول على انتاج كلائي للفصة.

كلمات مفتاحية: الفصة السنوية، الفصة، تربة ناقصة من الفوسفور، تثبيت الفوسفور في الانسجة، جودة الكلإ.

Résumé

Les luzernes annuelles ou médics (Médicago spp.) sont des légumineuses appétables et de bonne valeur nutritive. Elles permettent la fixation d'azote et assurent l'auto-régénération. Elles peuvent jouer un rôle important au sein des systèmes de production céréaliculture-élevage comme ceux pratiqués dans les régions arides et semi-arides du Maroc. Les travaux réalisés sur ces espèces fourragères ont constitué un élément majeur dans les recherches entreprises au Centre Aridoculture de Settat. Bien que le phosphore constitue un élément important pour la biomasse et la qualité, au Maroc peu d'études ont été effectuées sur la réponse des médics à la correction par des apports dans les sols déficients en cet élément. L'utilisation différentielle de P par les différentes espèces de Médicago n'est jusqu'à présent pas élucidée. Des essais en serre ont été réalisés en pots sur un Vertisol à bas niveau de P (2 ppm Olsen NaHCO3-P) fertilisé à 0, 50, 100, 200 ppm de phosphate en utilisant huit génotypes : M. blancheana L., M. rotata L., M. polymorpha L. cv. Serena et de deux écotypes locaux, M. scutellata Mill. cv. Sava, et M. trunculata Gaertn cv. Cyprus et un écotype local. De même, trois cultivars Cyprus, Serena, et Sava ont été mis dans un essai au champ sur un sol Palexeroll Petrocalcique peu profond et *déficient (4 ppm) en P avec des apports de 0, 15, 30, et 60 kg P ha-1. En serre, toutes les médics étudiées, avec une petite variabilité entre génotypes, ont eu une réponse positive ; exprimée par l'augmentation de la production de biomasse, aux apports faibles et moyens de P. Cependant, au-delà de 50 ppm aucune réponse n'a été obtenue alors que quelques réductions de rendement ont été observées à 200 ppm. Toutefois, l'absorption et la concentration de P dans les tissus ont augmenté avec le niveau élevé d'application. Au champ, les variétés Sava et Serena ont démontré une forte positive réponse aux apports de P et aussi Cyprus quand ces apports sont faibles. Le rendement de la variété Serena a été timide, sa croissance n'a pas été bonne, vraisemblablement due a une mauvaise nodulation. On conclue que sur les sols où le phosphore est un élément déficient, en dessous de 7 ppm (Olsen NaHCO3-P), l'apport des engrais phosphatés et du Rhizobium sp. est obligatoire pour obtenir une bonne production fourragère de médics.*

Mots clés : Luzernes annuelles, médics, sols déficients, concentration de P dans les tissus, qualité de fourrage.

Abstract

As palatable, N-fixing, self-regenerating annual legumes, medics (Medicago spp.) have potential importance in the livestock cereal based systems of Morocco's semi-arid dryland agriculture. Research on medics has been a major thrust at the Aridoculture Center in Settat. While phosphorus is important for biomass and quality, little attention has been given, in Morocco, to field response of medics in P-deficient soils, nor have genotypic differences in response to P been considered. The greenhouse phase of this study involved a low-P (2 ppm) Vertisol fertilized with 0, 50, 100, 200 ppm P fertilizer applications and five species; M. blancheana, M. polymorpha cv. Serena and two local ecotypes, M. rotata, M. scutellata cv. Sava, and M. trunculata cv. Cyprus and a local ecotype. Concurrently, three cultivars Cyprus, Serena, and Sava were field-tested on a shallow P-deficient (4 ppm) Petrocalcic Palexeroll at 0, 15, 30, and 60 kg P ha-1 fertilizer applications. All medics in the greenhouses were highly responsive to P, with some cultivar differences. However, beyond the 50 ppm P level there was no response, while some yield depression occurred at the 200 ppm level. Phosphorus uptake and tissue concentration increased with application rate. In the field, Sava and Serena were highly responsive; while Cyprus also responded to P at low P application. Growth of Serena was poor, presumably due to poor nodulation. Thus, where available soil P is deficient, i.e., less than about 7 ppm Olsen (NaHCO3) P, fertilization and nodulation are essential for a good medic stand.

Key words: Medics, soil P deficiency, tissue P concentration, forage quality.

Introduction

Agricultural output in the semi-arid dryland areas of developing countries is generally low and variable, being largely dependent upon the amount of rainfall and its distribution (Steiner et al., 1988). The North Africa-Middle East region, which is characterized by a Mediterranean climate with winter rainfall, is no exception to this generalization. The past two decades have seen an intensification of efforts to improve dryland-farming systems and to halt the decreasing per capita food production of most semiarid countries, the majority of which are in Africa. Morocco's agriculture is dominated by rainfed cereals, barley (*Hordeum vulgare L.*) and wheat (*Triticum* spp), which are mainly grown in the 250 to 500 mm yr-1 rainfall zone (Shroyer et al., 1990). The establishment of the Aridoculture Center in Settat (Ryan et al., 1989) has been a major boost to cereal research and related technology transfer.

Given modest increases in chemical inputs, improved varieties, and land management, Morocco's dryland area is viewed as having considerable potential for yield improvement (Crawford and Purvis, 1986). Barley occupies about 50% of the area sown with cereals. This equals the area of land devoted to bread wheat (*Triticum aestivum L.*) and durum wheat (*T. turgidum var. durum L.*). A considerable amount of land remains fallow at any given season, especially in drier areas with shallow soils. Fallow land produces variable weed stands and is used as a temporary pasture. However, production from this "weedy" fallow, in terms of livestock gain, is low. Thus, any potential moisture conservation, considered the main goal from fallowing, is lost by such a practice. With increasing land pressure, the proportion of fallowed land is dropping. Livestock is a necessary component beside cereals in the arid and semi-arid production systems. It transforms crop residues and failed crops from drought to animal products that are either used by the household or sold in the market.

In an effort to improve these temporary pastures, which represents up to 25% of the total land devoted to annual crops, and benefit the cereal crop as well, much hope is pinned on the use of annual medics (*Medicago* spp.). While indigenous medic species are found in weedy fallow, they are generally not present in sufficient amounts to significantly affect forage production or quality. Commercial use of medics, i.e., ley-farming systems, has spread from Australia to the Maghreb area of North Africa. Most of the commercial development of medic cultivars and management of dryland medic pastures has occurred in Australia (Clarkson et al., 1987). Local ecotypes have proved their usefulness in Morocco (Derkaoui, 1988). Research at the Aridoculture Center has dealt with medic management practices, plant collection, and phonological studies in terms of emergence, agronomic characteristics, and biomass yield in a wide spectrum of semi-arid environments. An increase in seeding rate was shown to increase biomass yield (Derkaoui et al., 1990). However, medics may not necessarily increase residual soil N after one cropping season. But with successive wheat/medic cropping over a 10-year period, considerable buildup in mineral and total N can occur under Mediterranean type conditions (Ryan and Abdel Monem, 1998). Indeed, medics in rotations can improve soil quality as reflected in increased soil organic matter content and improvements in physical properties such as aggregation and hydraulic conductivity (Ryan, 1998).

Many areas in the dryland zone are deficient in plant-available P (Abdel Monem et al., 1990). Thus, concern for P fertilization is a logical research topic to elucidate. Field research in the region with cereals and a range of food and forage legumes (Matar et al., 1988) suggests that about 5 to 7 ppm NaHCO3-P would be necessary for medics. Rudd (1972) indicated that medic pasture responses to superphosphate application were unlikely when soil P exceeded 30 ppm according to a different extraction procedure (Bray and Kurtz No. 1); optimal rates were 32-38 kg ha-1 in sandy soils and higher in heavy-textured soils. These P values appeared to be lower than those obtained by Dahmane and Graham (1981).

Rommann and Derkaoui (1987) found that superphosphate application increased medic forage production in a Calcixerollic soil where NaHCO3-P concentration was 13 ppm. However, differences were not observed between broadcast and banding application, nor was there a response to P when plants were water-stressed. Research with alfalfa (*Medicago sativa L.*) indicated a P deficiency when tissue P concentrations are less than 0.23 to 0.25%, depending on growth stage. Fertilization with P may also increase crude protein and P concentration and by then forage quality (Rhykerd and Overdahl, 1975). While most of the P studies in Morocco's dryland have focused on cereals (Azzaoui et al., 1990), the fertilization program expanded to include medics. This pioneer study of P-deficient soils simultaneously evaluated field response of three medic cultivars to applied P and that of a wider range of species and ecotypes in the greenhouse.

Material and methods

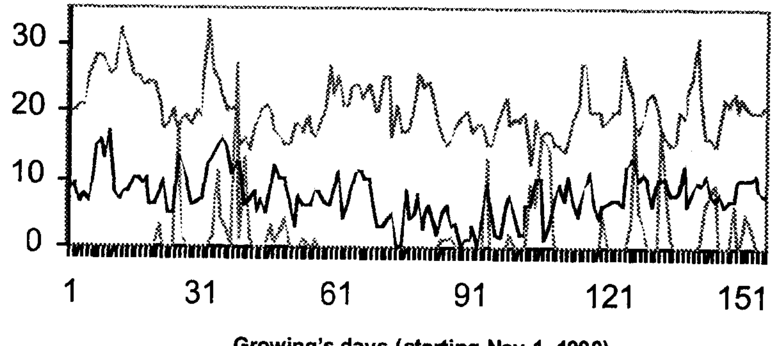
The field and greenhouse phases of the P study were conducted concurrently during the cropping season 1990-'91. The field trial involved three cultivars; Cyprus, Sava, and Serena, and four levels of P fertilizer (0, 15, 30 and 60 kg ha-1 hand-broadcasted as triple superphosphate) on a P-deficient (4.0 ppm NaHCO3-P) field adjacent to Settat. The soil was a shallow (25-35 cm) Petrocalcic Palexeroll, and is representative of the Chaouia region (Stitou, 1985). Other characteristics included low nitrate but high potassium levels, clay texture, and relatively high organic matter content (3.8%). The site was prepared by one pass of an offset-disc harrow, the common form of primary tillage in Morocco. The experiment was a split-plot arranged in a randomized complete block design with three replications. Main plots were plant genotypes, while sub-plots were P levels. Plot size was *4 _ 5 m.*

Fertilizer P was applied on December 2, while a few days later (December 7), medic seeds were hand-broadcasted and raked into the soil along with the fertilizer, to a 3-6 cm depth. The three cultivars used originated in Australia. Because of seed size and in order to have the same plant density, the larger-seeded cultivar of *M. scutellata* Mill, Sava, was sown at 40 kg ha-1, while small-seeded M. polymorpha L. cv. Serena and M. truncatula Gaertn cv. Cyprus cultivars were each sown at 10 kg ha-1. Following emergence, weeds were controlled by hand-pulling. At early pod formation, plots were harvested in spring (March 29) to estimate forage yield. Generally speaking, the growing season was warm (Fig. 1). The lowest reached temperature was 0°C in January 1991, while the highest was 31 in March 1991. Rainfall (277 mm) was lower than long-term mean precipitation (390 mm) and occurred between November 18, 1990 and early April 1991.

The greenhouse phase involved eight accessions involving five species: M. *blancheana L.*, M. *polymorpha* L. cv. *Serena* and two local ecotypes, one from Beni Mellal and the other from Tessaout, M. rotata L, M. scutellata Mill cv. Sava, and M. *truncatula* Gaertn cv. *Cyprus* and a local ecotype from Beni Mellal. Both M. *blancheana* and *Sava* have large seeds. Both cultivars also have upright growth habit, with M. *rotata* being semi-upright. The other accessions have small seeds and tend to grow prostrate. A P-deficient Vertisol (2.0 ppm NaHCO3-P) was put through a 6-mm sieve and placed in pots (5-kg). As the K status of the soil was marginal, K was mixed with soil at 200 ppm as K2SO4. Treatments of P were 0, 50, 100, and 200 ppm as monocalcium phosphate. Plants were thinned to six seedlings per pot after emergence. Pots were watered as needed with distilled water that was applied to the basins. Temperature in the greenhouse was maintained at 20-25°C. The experiment was arranged in a completely randomized design with four replications. The growing period was 13 weeks after which plants were cut at the flowering stage, dried at 65°C for 48 hours and weighed then analyzed for P contents using wet digestion procedure and spectrophotometric determination.

Results

Dry matter production at early pod formation indicated a marked field response to applied P even at 60 kg ha-1 rate (Table 1). Consistent responses were evident for Cyprus, up to 30 kg ha-1, and Sava cultivars, and for Serena, except at the lowest rate. The first yield increment with applied P (15 kg ha-1) increased Cyprus yield by 36% and produced nearly a twofold increase of the Sava cultivar; however, yields of Sava were the highest in all P applications. Cursory examination of the roots of Serena revealed little or no nodulation, in sharp contrast to the other two cultivars. Because growth of this cultivar was poor and it began early senescence, it was harvested th ee weeks earlier than the other two cultivars.



Growing's days (starting Nov.1, 1990)

Fig 1. Maximal (Tmax) and minimal (Tmin) temperatures and precipitations (Pmm) at Settat during the

Table 1. Medic dry matter production as influenced by P application on a P-7deficient soil in Settat, 1990-'91.

Cultivar	P (kg/ha)			
	0	15	30	60
	t/ha			
Cyprus	3.65	5.12	5.92	5.77
Sava	4.12	7.75	7.70	9.05
Serena	2.05	2.45	3.05	4.25

LSD = 0.43

With the other P-deficient soil (Vertisol) in the greenhouse, an expanded number of medic accessions exhibited a more accentuated, positive P response up to about the rate 50 ppm application rate (Table 2). Interactions between genotype and P application was present but not with a high magnitude. Depending on the initial control yields, response of most medics genotypes at 50 ppm P ranged from 150 to 500%; the exception was with one ecotype of M. polymorpha (Tessaout) whose growth was increased 13 times by P application at 50 ppm. However, beyond this level of application, there were no further yield increases for any medic species. Indeed, at the highest P level, there was a tendency for some species, particularly M. rotata, to decrease in yield; this latter species is not from Morocco and was introduced from ICARDA for experimental purposes.

Table 2. Biomass of medic genotypes and P application on a P-deficient soil in the greenhouse, 1990-'91.

Medic genotype	-P (mg/kg)			
	0	50	100	200
	g/pot			
M. blancheana	1.9	9.1	7.2	6.9
M. rotata	2.6	10.0	7.2	2.6
M. polymorpha (Beni Mellal)	1.9	11.5	8.8	11.7
M. polymorpha cv. Serena	2.5	14.3	14.4	11.1
M. polymorpha (Tessaout)	1.0	13.1	14.9	11.0
M. scutellata cv.Sava	4.3	18.4	19.0	16.6
M. truncatula (Beni Mellal)	3.4	8.1	6.5	6.4
M. truncatula cv. Cyprus	2.4	9.4	9.2	7.3
Mean	2.5	11.7	9.8	9.2

LSD = 4.4

The overall means yields reflected these trends, with the initial P level increasing yields over four *times that of the unfertilized* controls. The mean dry matter yields of the medics when averaged over unfertilized and P fertilized treatments reflect their yield potential in the field with adequate fertilization. These ranged from the highest yielding Sava to the lowest yielding M. rotata. Indeed *M. truncatula* (Cyprus) and its local ecotype, and *M. blancheana* performed little better than *M. rotata*.

In terms of P concentration in medic tissues, the increase was minor with low P application rate of 50 ppm (Table 3). It became significant at the high P rates. From 0 to 200 ppm of added fertilizer, P content in tissues doubled and in some cases it was threefold as in the case of M. rotata and the local ecotype of *M. truncatula*. Interaction between medic genotypes and P application was present to amplify the trend of the positive response. For instance, there was little change in P content of the local ecotype of *M. polymorpha* coming from Beni Mellal while a tremendous increase of tissue P occurred in *M. rotata*. Despite the absence of growth responses above the initial P level, increases in tissue P concentrations did occur. Averaged over cultivars, the mean P concentrations were, 0.29, 0.35, 0.49 and 0.68% for the 0, 50, 100, and 200ppm P levels, respectively.

Table 3. Medic P content as influenced by the genotype and P application on a P-deficient soil in greenhouse, 1990-'91.

	P (kg/ha)			
Medic genotype	0	50	100	200
	% P			
M. blancheana	0.27	0.30	0.32	0.48
M. rotata	0.30	0.37	0.57	1.00
M. polymorpha (Beni Mellal)	0.28	0.31	0.43	0.35
M. polymorpha cv. Serena	0.30	0.39	0.46	0.59
M. polymorpha (Tessaout)	0.34	0.33	0.43	0.62
M. scutellata cv. Sava	0.27	0.32	0.34	0.63
M .truncatula (Beni Mellal)	0.26	0.33	0.59	0.94
M. truncatula cv. Cyprus	0.30	0.45	0.66	0.81

LSD = 0.11

Discussion

The present data concur with literature that fertilizer P application on deficient soils increases dry matter production and also tissue P content (Dahmane et al. 1981, Rommann and Derkaoui, 1987). The significant field and greenhouse response of medic genotypes to applied P fertilizer added a new dimension to the endeavor to promote this forage crop in Morocco. It is encouraging that such yield increases could be evoked by as little as 15 kg P ha-1. As P remains available for several years (Rhykerd and Overdahl, 1975) and as P is also so essential for cereals in Morocco (Azzaoui et al., 1990), it is apparent that cereal P fertilization would benefit the subsequent medic crop rotated with it. Even where no further yield increases occur, it is likely that, based on tissue P data from the greenhouse, P fertilization would increase P content in forage-a considerable benefit in dryland Morocco, where sheep are dependent on low quality feeds mostly deficient in protein and phosphorus, such as stubble, straw, and weeds. As soil testing with the Olsen $NaHCO_3$ procedure is reliable for soils of the Mediterranean area (Ryan and

Matar, 1990), the key to efficient fertilizer use for medics, or any other field crop, is soil testing to establish if the field is deficient.

An interesting feature of the field trials was the poor response of the variety Serena. For reasons that are as yet unclear, this cultivar did not produce nodules in any significant quantity. This raises the question of specificity of soil Rhizobia and the need for commercial inoculation of the seed. Inoculation would be essential for this medic variety and probably others, in certain semi-arid areas, especially where legumes were not previously grown.

Successful field adaptation of medic in ley-farming also depends not only on adequate seeding rate, i.e., 10 kg ha-1 for small seeded and 40 kg ha-1 for large seeds (Derkaoui et al., 1990), but also on the use of higher-yielding cultivars. The greenhouse and field data here indicate the superiority of *M. scutellata* cv. *Sava* in comparison with other accessions. Not only do genotypes differ in their response to P, but also some may be adversely affected by high rates of P as in the case of *M. rotata* that exhibited the highest tissue P content at high P fertilizer rate. A possible explanation for the decrease in an adverse interaction between excess P and soil Zn. Further detailed work is necessary to establish the significance of this observation, since several areas of Morocco are naturally high in available soil P. On average, forage yields from the greenhouse consistently decreased with increasing P after the initial 50 ppm, level at which P started to accumulate in tissues. The response of local ecotype is encouraging and calls for additional investigations to promote these accessions into new medic varieties. While the use of medics in Moroccan dryland farming is in its infancy, the potential possibilities are tantalizing. Sufficient practical information such as seeding rates, cultivars, and P fertilization has been accumulated to put medics use on a more firm footing. Farmer acceptance is the next, and perhaps most difficult, obstacle.

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