summer, communities of *Salicornietalia* occur (1). Species of the communities of the *Trifolion maritimi* are well suited to the establishment of pastures on these areas and by draining the soils to remove excess water and using ecotypes resistant to flooding and salinity such as *Phalaris arundinacea, P. tuberosa, P. arundinacea* ×*P. tuberosa* hybrids, *Festuca arundinacea* ssp. *fenas, Alopecurus bulbosus, Agrostis stolonifera* var. *maritima, Trifolium* spp., *Lotus decumbens, Medicago* spp., *Melilotus* spp., *Tetragonolobus siliquosus* var. *maritimus* and certain exotic species, such areas could be used for cattle production. Under irrigation it is possible to maintain leys or pastures of *Lolium multiflorum, L. rigidum, Trifolium pratense, T. repens* var. ladino, *T. fragiferum, T. alexandrinum* and *T. resupinatum*.

Importance of dew

Dew is very important for the establishment of pastures in areas of low rainfall and high atmospheric humidity. In March 1955 an assessment was made of the importance of dew on the littoral of Almeria. In this region, dew can cause a superficial leaching of saline soils, allowing invasion by oligotrophic communities (e.g. *Tillaea muscosa, Trifolium suffocatum, Riccia* spp.) in an environment characterized by steppe vegetation (*Lygeum spartum, Plantago ovata, Matthiola lunulata, Iris sisyrinchium*). Dew deposition is favoured by local cooling, especially in thick, herbaceous vegetation and in shade. There is need for research on methods for utilizing dew and promoting its deposition.

In Almeria, spineless prickly pear is commonly grown. In its shade there is intense precipitation of dew and ephemeral oligotrophic plants develop in consequence of this. The maximum amount of shade and dew deposition could be obtained by growing prickly pear in rows in an E-W direction. Park grasslands, or grasslands interspersed in forests, could benefit from this supplementary precipitation (which may amount to several hundred mm per year), resulting in sustained pasture production and counteracting the accumulation of salinity in spring.

Complementary research

The preliminary research inspired by studies of autecology and plant sociology can be extended to more precise experimental work. Resistance to increasing salinity and to different ionic combinations can be studied in water cultures and in special substrata. Plant-pigment studies in relation to dry weight could result in an assessment of certain dynamic properties of vegetative cycles, as has been done in phyto-plankton research (3). Studies of artificial communities established under defined conditions of environment and with control of competition, utilization and manuring can materially assist our understanding and use of different pasture types.

Problems in the exploitation of grasslands in the Mediterranean region appear complex, but the methods discussed above offer an overall view of them and provide a scientific basis for their solution. Ecological study of interactions between the three components of the system, namely, soil, plant and animal, can bring better understanding of the problem and help also to achieve maximum production within a given environment.

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PAPER 14A/4

PLANT ECOLOGY AND PASTURE PROBLEMS IN THE MEDITERRANEAN PROVINCES OF SPAIN

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Summary. Fodder production is an ecological problem in which the soil/pasture/animal system must be regarded as a whole. Animals can change the environment, modify the soil and alter the balance of competition among grassland plants. This concept has been developed in the studies in Eastern Spain reported in this paper.

In the Mediterranean climate of dry summers and cold, wet winters, stands of perennial herbage species are difficult to maintain, but there is no paucity of species well suited to the environment. The characteristics required of a perennial herbage plant include rapid development after the first onset of autumn rains, with growth continued into the following early summer after the cessation of rains, and resistance to grazing.

From the results of observations of plants grown both as spaced plants and as members of a plant community, it is suggested that types could be selected from existing wild material which could form the basis of new cultivars.

The 'dehesa' grasslands of Spain are discussed. These are basically park-like grasslands in which the scattered trees and shrubs which are present create a micro-climate favourable to the herbaceous vegetation. The implications of this relationship for pasture production in sub-arid regions of Spain and elsewhere merit more detailed study. The importance of dew is noted, especially in environments such as littoral regions which have low rainfall and high atmospheric humidity.

Résumé. La production de fourrage est un problème écologique dans lequel le système sol/pâture/animal doit être considéré comme un tout. Les animaux peuvent changer le milieu, modifier le sol et changer l'équilibre de concurrence entre les plantes d'herbages. Ce concept a été acquis au cours des études entreprises dans l'est de l'Espagne et rapportées dans la présente communication. Dans le climat méditerranéen, comportant des étés secs et des hivers froids et humides, il est difficile d'entretenir des peuplements d'espèces fourragères vivaces, mais il existe de nombreuses espèces bien adaptées au milieu. Les caractéristiques exigées d'une plante fourragère vivace comprennent un développement rapide après les premières chutes de pluies automnales, avec une croissance se poursui-

vant au début de l'été suivant, après la fin des pluies, et la résistance à la pâture. A partir des résultats d'observations sur des plantes ayant poussé à la fois en tant que plantes séparées et en tant que membres de communautés végétales, l'auteur considère que des types pourraient être sélectionnés à patrir des espèces sauvages existantes pour former la base de nouvelles variétés cultivées. Il examine les herbages 'dehesa' d'Espagne. Ces herbages sont fondamentalement semblables à des prés-bois; les arbres et arbustes épars qui sont présents créent un micro-climat favorable à la végétation herbacée. L'interêt de ces relations herbe-arbres ou arbustes pour la production de pâtures dans les régions sub-arides d'Espagne et d'ailleurs méritent une étude plus détaillée. L'importance de la rosée est notée, en particulier dans des milieux comme les régions littorales qui ont de faibles précipitations et une humidité atmosphérique élevée.

Zusammenfassung. Futter-Erzeugung ist ein ökologisches Problem, bei dem Boden/Weide/Tierbestand als eine Einheit angesehen werden müssen. Tiere können die Umgebung beeinflussen, den Boden verändern und das Gleichgewicht zwischen den verschiedenen Weidepflanzen aufheben. Diese Auffassung ist durch Untersuchungen in Ost-Spanien, über die in diesem Referat berichtet wird, bestärkt worden. Im Mittelmeer-Klima mit seinen trockenen Sommer und kalten, nassen Winter-Monaten sind Bestände von perennierenden Grasarten nur schwer aufrechtzuerhalten, jedoch herrscht kein Mangel an Arten, die der Umgebung gut angepasst sind. Die Merkmale, die von einer perennierenden Grasart verlangt werden, schliessen rasche Entwicklung nach dem ersten Herbstregen ein, mit Wachstumsfähigkeit, die bis zum nächsten Frühsommer, nachdem die Regenfälle aufhören, anhält und gute Widerstandsfähigkeit gegen Abgrasen. Auf Grund von Beobachtungen von Pflanzen, die sowohl als Einzelpflanzen als auch in Mischung gezogen wurden, kam man zu dem Schluss, dass Typen aus dem vorhandenen wild-vorkommenden Material ausgewählt werden könnten, die die Grundlage für neue Kulturen geben würden. Es werden sodann die 'Dehesa' Gebiete Spaniens besprochen. Das ist im wesentlichen Parkähnliches Grünland, in dem vereinzelte Bäume und Sträucher ein Mikroklima schaffen, das günstig für die Entwicklung von Gräsern ist. Die Schlussfolgerungen, die aus diesen Wechselbeziehungen für die Weideland-Produktion in den halbdürren Gebieten Spaniens und auch anderwärts zu ziehen sind, sollten genauer untersucht werden. Es wird auf die Bedeutung von Tau hingewiesen, besonders in den Küstengebieten, die geringen Regenfall und hohen atmosphärischen Feuchtigkeitsgehalt aufweisen.

Introduction

The problems associated with the production of forage are basically ecological in nature and the soil/pasture/animal system must be considered as a whole if any established system of production is to be maintained. In unfavourable climates, biocoenotic surveys are necessary to ascertain the point of equilibrium associated with the best utilization of resources. There is a need for the study both of plants adapted to such climates and of grazing animals best suited for their exploitation over extended periods. The present paper is limited to a consideration of botanical aspects only, and the basic principles associated with them.

In pasture communities the individuals forming those communities and the relationships between them must be considered. The grazing animal and man can change the environment by modifying the soil fertility and changing the balance of competition between plants. A knowledge of the plant community and its evolution must be based on taxonomy and autecology, since these are basic to pasture exploitation. The concept that any knowledge of plant communities and their evolution must be based on taxonomic and autecological studies has been developed in studies of the pastures of Eastern Spain and certain general principles which have proved useful in solving problems posed by Mediterranean pastures are set out in this paper.

Single-species population studies

Mediterranean pastures contain many species which are eaten by livestock. Direct observation of the grazing animal enables those species able to resist continuous grazing and which can provide feed at critical periods in summer and autumn to be recognized. It is not sufficient merely to identify the plant species; their ecotypes and growth rhythms must also be known. For the autecological study of types, the method proposed by FAO (9, 10) is used in Aragon (4). In the experiments reviewed here no manure was used and the plants were sown in natural soils and the spontaneous flora suppressed by repeated weeding.

It is clear that ecotypes differ in developmental rhythm, summer dormancy, tiller production, etc., and their study has led to the development of the concept of syngenetic natural selection (5, 8), the use of which has made it possible to establish stable pasture communities under controlled management. It seems safe to assume that in environments associated with forest climaxes, most European pastures have been formed by syngenetic natural selection. Selection pressure exerted by grazing animals has singled out ecotypes adapted to resist repeated grazing. Ecotypes in traditionally overgrazed old pastures have a dense, prostrate habit and are resistant to trampling. As there are many forms of pasture farming, many different ecotypes adjusted to them exist.

Under the less favourable climate of the Mediterranean areas belonging to the *Quercion ilicis* and the *Oleo-Ceratonion* zone, 2 factors are of paramount importance, namely, climate and soil. Ecotypes become adapted to the climatic rhythm and to the seasonal changes in soil properties which are a consequence of climatic fluctuations. Erosion is also a soil factor of importance under Mediterranean climates.

In such climates with dry summers and rainfall mostly confined to the cold season, it is difficult to maintain pastures of perennial species, and deep-rooted plants which can tolerate the summer sun must be sought. In deeper and moister soils, salinity occurs in summer and this must be borne in mind when selecting ecotypes. The rapidity of germination after the first rains in autumn has to be ascertained, and those ecotypes which show rapid development must be selected. Experience has shown the value of many Mediterranean ecotypes of *Dactylis glomerata*, *Hordeum bulbosum*, *Phalaris tuberosa*, *Festuca arundinacea*, *Hedysarum coronarium*, *Lotus creticus*, *L. corniculatus* ssp. *decumbens*, *Trifolium fragiferum*, *Medicago sativa* (strains resistant to nitrate accumulation) and *Onobrychis sativa*. In addition to these perennials there are many valuable annual species.

Among perennials it is important to select for at least 4 characters: (1) rapid autumn development, (2) strong winter growth, (3) higher productivity towards the end of spring, and (4) resistance to grazing. In very dry environments with mild winters, it is possible to maintain stands of *Hyparrhenia pubescens*, *H. hirta*, *Lotus creticus* and appropriate annuals. *Cynodon dactylon* is inactive in winter and seems less promising, except in particular environments. *Ampelodesma mauritanica* and *Eragrostis* spp. have hard, coarse leaves and are unpalatable to sheep, though it may prove possible to select ecotypes to suit cattle or horses. In the Mediterranean region resistance to cold is not important, except where the climate is continental, such as in Aragon, and parts of Castille, and in such regions as the Balkans and North Africa.

Community studies

In most grasslands where annuals predominate, a characteristic phenology is found. We can select as an example the island of Minorca, where periodicity is strongly developed. Rainfall in Minorca is about 600 mm per annum, of which half falls during October-December. Farming is based on cattle and from November to June, livestock graze natural pastures composed of annuals and leys based on *Hedysarum coronarium*. Thereafter, the cattle feed on grass stubbles, lucerne hay and other feeds imported from the mainland.

The rains during October to November leach out the mineral nutrients in the surface soil and a range of annual legumes (e.g. *Medicago hispida*, *M. tribuloides*, *Lotus ornithopodioides*, *Vicia* spp.) develop in the resulting low-fertility environment. The decreasing rainfall and increasing sunshine of spring reverse the soil-nutrient circulation and cause an increase in nitrates and other nutrients, which results in the development of a nitrophilic flora, including *Lolium rigidum*, *Phalaris* spp., *Hordeum murinum*, *Bromus* spp., *Lotus edulis*, *Galactites tomentosa*, *Echium plantagineum*, *Euphorbia* spp., *Kentrophyllum lanatum* and *Carlina* spp. At the end of spring only the most nitrophilic species remain, together with other species rejected by cattle. In summer only deep-rooted plants and those resistant to salinity remain green. A similar succession of grassland communities is to be observed over wide areas of the Mediterranean region.

The tendency for *Hedysarum coronarium* leys to be short-lived and to be invaded by nitrophilous species must be attributed to these edaphic factors, and both annual pastures and leys based on *H. coronarium*/perennial grass mixtures must be fertilized in autumn to counteract the leaching of nutrients from the top-soil. Such fertilizer treatments favour the rapid growth of grasses without adversely affecting legume growth. Suitable rates of fertilizer would appear to be 300–600 kg superphosphate applied in September, followed by applications of 50–100 kg ammonia nitrosulphate (28% N) and 50–100 kg KCl after every substantial fall of rain in autumn (there are normally 2 or 3 such falls in this season); it is not advisable to apply fertilizers in spring.

There is a particular need for detailed studies of the Spanish 'dehesa', which are park-like grasslands with scattered evergreen oaks. These range in type from grasslands not subject to any special culture and which are the result of clearing areas under evergreen oaks or wild olive shrubs, to sown pastures in either natural or planted woodland. Other pastures of this kind may be suitable for planting with almond or olive trees or such species as *Ceratonia siliqua*, *Phillyrea* spp., *Robinia pseudacacia*, *Gleditschia triacanthos* and *Acacia* spp. (8). Trees with deep root systems and which cast relatively light shadow may be expected to buffer edaphic fluctuations, retard the autumnal leaching of nutrients from the top-soil and prevent excessive concentration of salts in the soil during summer.

In wooded areas it would be possible to establish and maintain pastures cheaply by clearing undergrowth and thinning out the trees (leaving such species as *Quercus ilex*, *Phillyrea* spp., *Olea oleaster*), fertilizing with superphosphate (150–300 kg/ha) and sowing in autumn such species as *Medicago tribuloides*, *Lolium rigidum*, *Trifolium subterraneum*, *Dactylis glomerata* (Mediterranean strains) and *Lotus creticus* (7). The 2 last-named species are better transplanted than sown. Pastures of *Hedysarum coronarium* with appropriate grasses (6) on deep farmland soils would yield silage in spring, thereby complementing irrigated leys based on lucerne/grass.

Species suitable for seeding both natural and artificial park-type grasslands include *Phalaris tuberosa*, *Hordeum bulbosum*, *Hedysarum coronarium*, *Dactylis glomerata*, *Oryzopsis miliacea*, *Festuca arundinacea* and the annual species. The use of such species will prolong the seasonal productivity of grasslands and the trees offer to livestock protection from the sun. The composition of the pastures must be related to climate, soil and livestock use. Shallow depressions, often poorly drained in winter and brackish in summer, carry communities ranging from the *Trifolion maritimi* (1) to the *Juncion maritimi* (1, 2). In places, communities of *Phragmitetalia* (1) develop and where salinity is high in