Cereal and livestock production in Algeria
The potential for increasing

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E. D. Carter

Centro Internacional de Mejoramiento de Maíz y Trigo
THE POTENTIAL FOR INCREASING CEREAL AND LIVESTOCK PRODUCTION IN ALGERIA
A report prepared for CIMMYT
and the
Ministry of Agriculture and Agrarian Reform, Algeria

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CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO 1975
International Maize and Wheat Improvement Center, Apdo. Postal 6641, Mexico 6, D.F. Mexico
Correct citation: E.D. Carter. 1975. The potential for increasing cereal and livestock production in Algeria, Centro Internacional de Mejoramiento de Maíz y Trigo, Mexico City. 54 p.
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FOREWORD

Since 1971 CIMMYT has been helping the governments of Tunisia and Algeria test the potential value of a rotation of winter annual legume pasture (Medicago spp.) and wheat for replacing the present weed fallow-wheat rotation currently used in these countries.

During March-April 1974, Mr. Edward D. Carter, agronomist, Waite Agricultural Research Institute, visited Algeria as a CIMMYT consultant to study the potential for increasing crop and livestock production in Algeria if a legume pasture-wheat rotation was adopted.

Because of the potential value of this cropping system in other areas of the Near East and Mediterranean region, and the interest already generated by the research in Tunisia and Algeria, CIMMYT has decided to publish and distribute Mr. Carter's report.

CIMMYT appreciates the enthusiastic, thorough, and expert manner in which Mr. Carter accomplished this survey and report, and wishes to acknowledge the cooperation of the University of Adelaide in making Mr. Carter's services available.

The financial assistance provided by the Ford Foundation to carry out adaptive research on the farming system and to support this survey of the system's potential is gratefully acknowledged.

K.W. Finlay
Deputy Director, CIMMYT
1/12/74
In Algeria, as in other countries of North Africa and the Near East, there has been increasing concern at the deficit in food production despite the national agricultural development programmes and the aid from bilateral and multilateral agencies. The Algerian Government's desire to achieve national self-sufficiency in durum and soft wheat production and to promote agricultural research led to the establishment of the CIMMYT outreach programme in Algeria in October 1971. Since then the "Projet Cereales" (Cereals Project) has grown into an exemplary cooperative project involving the Algerian Ministry of Agriculture and Agrarian Reform (MARA), CIMMYT, FAO/UNDP and the French CCCE. Each group has a specific role in helping to raise cereal production.

However, in the diverse agricultural environments of Algeria there is also an urgent need to examine problems of pasture and livestock production and the scope for improving crop-livestock integration. In this respect Algeria is fortunate in having great scope for pasture improvement and livestock production in the traditional cereal-growing areas and even greater potential for pastures and livestock production in the higher-rainfall areas.

The report that follows represents a broad appraisal of the existing cereal and livestock situation in Algeria and the opportunities for increasing both cereal and livestock production. I have avoided reporting on well-known, and relatively static physiographic, climatic and edaphic features of the country and have concentrated on those aspects related to the dynamic agricultural and pastoral scene, and the potential for change in Algeria.

My first visit to Algeria was as a member of the TAC Mission in April 1973 (Skilbeck et al 1973). My second visit during March-April 1974 was spent on attachment to the CIMMYT group in the Cereals Project based in Algiers. However, to gain the necessary background and perspective to the crop and livestock industries I travelled extensively in the agricultural regions of northern Algeria from eastern to western Algeria and from the coastal regions in the north to the steppe regions on the southern side of the cereal zone. This travel (involving some 10,000 km by road plus air travel) has given me a clear picture of the existing and potential land use and some of the related agronomic, economic and social problems.

It was soon obvious to me that there were striking ecological similarities between Algeria and southern Australia and that Australia had a great deal to offer in the science and technology of land clearing, pasture improvement and general techniques related to cereal and livestock production and integration of these enterprises.
The terms of reference for my Algerian studies in 1974 included:

1. Surveying the indigenous and naturalized pastures in the cereal belt and adjacent hill country (too steep for safe cropping) to assess the occurrence of pasture and forage legumes.

2. Appraising the recent sowings of Medicago species in the cereal belt.

3. Indicating the potential scope for:
   (i) improvement of existing stands of mixed pasture containing legumes by dressing with phosphatic fertilizers;
   (ii) improvement of other areas by introduction of Medicago spp. (and other legumes) together with appropriate fertilizers (mainly soluble phosphates).

4. Assessing the broad implications of improved crop-livestock integration, based on the use of pasture and forage legumes in cereal rotations, on both food crop and livestock production.

My thanks are due to the many people in Algeria who helped me to fulfill my mission and to make my stay both useful and enjoyable. I am especially grateful to Dr. McCuistion, Dr. Nelson and Messrs. Floyd and Plouin of CIMMYT; Mr. Kadra, Director of the Cereals Project, and his staff; Messrs. Golusic, Bakhtri, Impiglia and Hadzic of FAO; Messrs. Ducousso, Maubert and Morel of CCCE and Professor Conesa and his assistants of INA, University of Algiers, for arranging field visits and discussions in Algeria.

Finally, it is a pleasure to record my thanks to CIMMYT for providing financial aid to enable me to undertake these studies in Algeria.

Edward D. Carter
EDWARD D. CARTER
Department of Agronomy
Waite Agricultural Research Institute

2/10/74
DEFINITIONS OF PASTURES, FORAGE CROPS, FODDER, AND ZONES

1. Pasture, Forage Crops and Fodder

While there are no universal definitions of these terms, the following definitions apply to the terms, listed below, that are used throughout the report.

(1) Pasture: A dynamic community of plants subjected to the various influences of the grazing animal (treading, defoliation, recycling of nutrients, dispersal of seeds). The pasture may be a mono-specific sward or a complex community of many genera and species.

(2) Native Pasture: Pasture dominated by indigenous perennial species (but often with associated annual species), including both climax and disclimax pastures.

(3) Natural Pasture: Volunteer (or spontaneous) pasture resulting from the activities of man and his grazing animals but without artificial sowing. Natural pasture is commonly characterised by dominance of annual species, frequently naturalized species introduced from elsewhere. The volunteer species may be the same species as are frequently sown, e.g. the spread of Medicago truncatula and Trifolium subterraneum in southern Australia.

(4) Sown Pasture: Annual and/or perennial species sown (usually with fertilizer) to increase the livestock carrying capacity of the area. The process is also referred to as pasture improvement when one or more species is introduced either on cultivated soil or into native or natural pasture.

(5) Permanent Pasture: Pasture developed by sowing perennial species with or without associate annuals and usually in higher-rainfall areas. The perennial species confer stability of botanical composition.

(6) Rangeland: Arid-zone pasture (including steppe) dominated by perennial species and generally not capable of improvement. Conservative stocking is obligatory.

(7) Forage Crop: Green crop sown to supplement normal pasture and frequently cut and carted to feed livestock. These forage crops may be sown annual species e.g. barley-vetch for winter feed; turnips, sudan grass etc. for summer feed; or perennial species like lucerne.

(8) Fodder: Any dried and stored or conserved feedstuff e.g. cereal hay, straw, cereal grain, pasture hay, forage hay, swedes, fodder beet, etc.
2. Zones of Algeria

Although there is no clear line of demarcation between zones, the following three zones are referred to throughout the report.

(a) Higher-rainfall Zone: > 600 mm mean annual precipitation. The north eastern region of Algeria is capable of supporting permanent or semi-permanent, highly-productive grazed pastures based on both annual and perennial legumes (mainly *Medicago* and *Trifolium* species) and annual and perennial grasses (mainly *Lolium*, *Phalaris* and *Festuca* species). This zone, which is bounded in the north by the Mediterranean Sea and approximately by a line through Algiers, Blida, Medea, Bouira and Souk-Ahras to the Tunisian border, is mainly elevated land varying from undulating through hilly to mountainous. This zone which is too wet and/or too steep for cereal cropping is potentially an ideal breeding and fattening area for sheep and cattle and the obvious area for development of the dairy industry.

(b) Cereal Zone: 350-600 mm mean precipitation. This large discontinuous zone extending approximately 1000 km from Tunisia in the east to Morocco in the west and from the Mediterranean coast southwards for up to 150 km is ideally suited to mixed cereal-livestock enterprises incorporating annual *Medicago* species in the crop rotation. Elevation varies from near sea level up to 1000-1200 m on the high plateau.

(c) Steppe Zone: 200-350 mm mean annual precipitation. This large zone of c. 20 million hectares occupies a band of country extending right across Algeria between the cereal zone and the very arid Saharian rangelands (Chellig 1974b). Le Houerou (1972) proposed four main categories of this steppe zone as follows:

1. Gramineous steppe (e.g. Alfa grass, *Stipa tenacissima*)
2. Chamaephyte steppe (e.g. sage-brush, *Artemesia herba alba*)
3. Nanophanerophyte steppe (mixture of chamaephytes and larger shrubs)
4. Crassulescent steppe of halophytes (e.g. *Atriplex halimus*)

Although cultivated on the wetter fringes, this steppe is too dry for reliable rainfed cereal cropping but it is suitable as a livestock breeding area, for supplying sheep to the cereal zone and higher-rainfall zone. Conservative stocking is essential to preserve the steppe.
I. INTRODUCTION

1. General Background Information

The physical environment and agriculture of North Africa was described by Nuttonson (1961) while the general ecology and land use was reviewed by Le Houerou (1970). More recently, the broad agricultural and social problems relating to the deficit in food production in the Region comprising both the Near East and North Africa were summarized in the report of the Research Review Mission to the Near East and North Africa (Skilbeck et al. 1973). This Region is shown in Figure 1 while the current land use in Algeria is summarized in Table 1.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Socialist Sector (hectares)</th>
<th>Private Sector (hectares)</th>
<th>Total Area (hectares)</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Cereals for grain</td>
<td>768,710</td>
<td>2,459,460</td>
<td>3,228,170</td>
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<tr>
<td>Other annual crops</td>
<td>184,660</td>
<td>128,200</td>
<td>312,860</td>
<td>0.7</td>
</tr>
<tr>
<td>Total annual crops</td>
<td>953,370</td>
<td>2,587,660</td>
<td>3,541,030</td>
<td>8.3</td>
</tr>
<tr>
<td>Fallow land</td>
<td>584,790</td>
<td>2,122,490</td>
<td>2,707,280</td>
<td>6.4</td>
</tr>
<tr>
<td>Vineyards</td>
<td>260,230</td>
<td>40,110</td>
<td>300,340</td>
<td>0.7</td>
</tr>
<tr>
<td>Orchards and Vegetables</td>
<td>90,750</td>
<td>161,460</td>
<td>252,210</td>
<td>0.6</td>
</tr>
<tr>
<td>Pasture</td>
<td>15,310</td>
<td>19,170</td>
<td>34,480</td>
<td>-</td>
</tr>
<tr>
<td>Rangeland</td>
<td>326,780</td>
<td>34,018,600</td>
<td>34,345,380</td>
<td>80.8</td>
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<tr>
<td>Unproductive farm lands</td>
<td>71,050</td>
<td>1,197,620</td>
<td>1,268,670</td>
<td>3.2</td>
</tr>
<tr>
<td>Total area</td>
<td>2,302,280</td>
<td>40,147,110</td>
<td>42,449,390</td>
<td>100</td>
</tr>
</tbody>
</table>


2. Some Agricultural Problems

In Algeria, despite the national agricultural development programmes and the aid from bilateral and multilateral agencies there is a serious deficit in the production of cereal grains, meat and milk for the rapidly expanding population. These deficits in food production must be seen against a background of:

(1) Declining soil resources - through desert encroachment in the steppe
   - through water erosion in the higher-rainfall areas

(2) Poor soil structure - both a cause and an effect of deep ploughing
   - associated with low levels of soil organic matter
   - leading to increased costs of tillage

* As specified by FAO, North Africa comprises Algeria, Morocco and Tunisia.
(3) Unsuitable tillage and sowing equipment - increasing costs of production
   - decreasing crop yields

(4) Serious weed problems - decreasing yields of cereals
   - increasing costs of cereal production
   - through inadequate pasture competition

(5) Poor volunteer pastures - low in legumes and in nutritive value
   - low in density and in productivity
   - receiving inadequate phosphatic fertilizer

(6) Inadequate crop-livestock integration - contributing to overgrazing and
   erosion problems and to undergrazing and consequent weed problems

(7) Insufficient trained personnel for agricultural production, research and
   extension

These seven major agricultural problem areas, representing major constraints to
production, are all interrelated and will be discussed under later sections.

The reasons for the human population explosion are well known and need no
elaboration. Less known is the fact that at the same time there has also been a
substantial increase in ruminant livestock numbers (Table 2).

**TABLE 2**

<table>
<thead>
<tr>
<th></th>
<th>1966</th>
<th>1972</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population ('000)</td>
<td>12,654</td>
<td>15,016</td>
<td>+ 3.73</td>
</tr>
<tr>
<td>Cattle ('000)</td>
<td>801</td>
<td>863</td>
<td>+ 1.55</td>
</tr>
<tr>
<td>Sheep ('000)</td>
<td>7,129</td>
<td>8,420</td>
<td>+ 3.62</td>
</tr>
<tr>
<td>Goats ('000)</td>
<td>2,322</td>
<td>2,200</td>
<td>- 1.11</td>
</tr>
</tbody>
</table>


The prospects for expansion of dryland farming in Algeria are not good (Downes
and Faunce 1973). In fact there will need to be a retraction from the dry areas to
protect the grazing value of the steppe. The desire for greater cereal production
and the availability of mechanized tillage has meant an expansion into the Algerian
steppe where there is approximately one million hectares of cereals. Unfortunately
this is not a stable area: it is estimated that some five million hectares of
Algerian steppe have been destroyed by cultivation for cereal cropping (Le Houerou
priv. comm.). This has increased competition for land resources, increased grazing
pressure on remaining steppe and generally aggravated the traditional conflict
between the cropper and the shepherd i.e. between settled agriculture and nomadism.
Thus the steppe is declining in area and deteriorating in productivity. Hence there
is a clear need for crop-livestock integration within the main cereal zone, between
the steppe and cereal zone, and between the steppe and higher-rainfall zone to help
stabilize production from the steppe.
The Region comprising North Africa and the Near East (countries as shown on the map) had a mid-1973 population of 208 million. At that time the Algerian population was estimated to be 15.5 million with annual rate of population growth of 3.3 per cent and a projected population of 23.9 million by 1985.
Increased livestock production in Algeria will depend on fertilized volunteer and sown leguminous pastures in both the medium-rainfall cereal-livestock zone and the higher-rainfall grazing country. Machinery such as this Australian clover and medic harvester and seed drill are needed for use in pasture improvement programmes.

The successful establishment of medics and clovers, with a corresponding reduction in fallow, will improve crop yields and increase total cereal production in Algeria.
Chellig (1974a) has reviewed the problems of animal production on the Algerian steppe and described the role of cooperatives in the development of the steppe and the settlement of nomads (Chellig 1974b). However, though there are undoubtedly some social advantages (e.g. availability of schooling and medical care) in such settlements the plain ecological fact is that the only reliable method of preserving the long-term productivity of the steppe is to reduce both the livestock numbers and human population on the steppe. This can be done by greatly increasing pasture and forage production in the cereal crop zones and higher-rainfall areas of Algeria - i.e. to provide alternative grazing to encourage population and livestock movement from the steppe (Carter 1974a).

While the steppe can be conservatively stocked by breeding flocks and herds there must be the organization and facilities for a maximum annual offtake of livestock from the steppe - direct to market or to grazing areas and feed lots in the cereal zone or higher-rainfall areas. Road transport of livestock and water tanker trucks could play a very useful role in reducing the problems of overgrazing and excessive treading damage, especially in times of drought.

Thus the cereal zone and higher-rainfall zones of Algeria hold the key to improvement of both cereal crop and livestock production.

Despite the various international agricultural research programmes dealing with pasture and forage species (e.g. Le Houerou 1971, Maignan 1971, Gallacher 1972) there has been no marked progress in pasture improvement in Algeria. No doubt part of the reason lies in the fact that a grossly disproportionate emphasis has been placed on imported species and cultivars and too little attention paid to local species and ecotypes. In particular, there has been negligible research devoted to the ecology, production, management and utilization of the wide range of indigenous annual Medicago species existing in Algeria. Furthermore, a great deal of effort has been devoted to the introduction and assessment of grass species when it is obvious that there is no shortage of local species and ecotypes of grass. Having regard to the current problems of Algerian agriculture it is quite apparent that research related to pastures and forage crops should certainly concentrate on legumes.

It seems appropriate to relate the current state of agriculture in Algeria to present and past treatments and long-term traditional practices; also, on the assumption that methods will change, to predict the potential role of pastures and forage crops in increasing the production of both cereals and livestock in Algeria. In order to provide a firm basis for these predictions it is useful to compare the climate, soils, vegetation and agricultural production of Algeria and South Australia. Extrapolations, with due reservations, can then be made from the South Australian to the corresponding Algerian agricultural zones.
### TABLE 3
SOME COMPARATIVE CLIMATIC DATA FOR MEDICAGO AREAS

<table>
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<td>Altitude (m)</td>
<td>Precip. (mm)</td>
<td>Max. Temp. (°C)</td>
<td>Min. Temp. (°C)</td>
</tr>
<tr>
<td>Alger (Port)</td>
<td>5</td>
<td>647</td>
<td>30.9</td>
<td>9.8</td>
</tr>
<tr>
<td>Annaba</td>
<td>58</td>
<td>674</td>
<td>29.8</td>
<td>7.9</td>
</tr>
<tr>
<td>Berrouaghia</td>
<td>930</td>
<td>593</td>
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</tr>
<tr>
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<td>523</td>
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</tr>
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<td>Tlemcen</td>
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<td>415</td>
<td>33.7</td>
<td>2.7</td>
</tr>
</tbody>
</table>

---

$\dagger$ Mean annual precipitation  
* Mean maximum temperature for the hottest summer month i.e. July in Algeria and January in southern Australia  
$\ddagger$ Mean minimum temperature for the coldest winter month i.e. January in Algeria and July in southern Australia

Sources: Climatic Averages Australia, Bureau of Meteorology, 1956  
Bounaga, Chaumont and Paquin (1971); Le Houerou (1971)
II. COMPARISONS BETWEEN ALGERIA AND SOUTHERN AUSTRALIA

1. Climate, Soils and Vegetation

The climate of northern Algeria and of the southern part of South Australia and Western Australia, also parts of Victoria and New South Wales, is of the classical Mediterranean type with rainfall concentrated in the cooler season when days are shorter. While the definitions of arid and semi-arid environments vary, it is generally agreed that the 350 mm annual rainfall isohyet approximates the northern limit of the steppe vegetation and the lower limit for regular and productive cereal growing under dryland farming conditions in Algeria (Le Houerou 1970). However, there is no clear line of demarcation: obviously it depends on slope, aspect, soil texture and water-holding-capacity of the soil. In South Australia and Victoria the corresponding rainfall isohyet for reasonable success in dryland cereal production is about 300 mm. However, in Western Australia on light-textured soils and under conditions of regular and well-defined winter-rainfall conditions the lower limit for successful cereal growing is about 250 mm. The apparently higher rainfall requirement for successful cereal farming in Algeria may imply a greater rainfall variability in the semi-arid regions at the margin of the cereal zone in Algeria than in the cereal zones of South Australia, Victoria and Western Australia but there is no clear evidence of this. It could well be merely a reflection of the fact that in these areas of Algeria, soils are generally of heavier texture than in South Australia and Victoria which, in turn, have soils of heavier texture than the corresponding cereal cropping soils of Western Australia. In both countries, variability in annual precipitation increases in inverse relation to the average rainfall.

Some comparative climatic data for the Medicago areas of Algeria and of South Australia, Victoria and New South Wales are summarized in Table 3. Temperatures depend on latitude, altitude and degree of continentality. While the mean daily minimum temperatures for January in Algeria and July in southern Australia are 7-9°C in the coastal regions, in Algeria this minimum may decline to near 0°C at 1000-1200 metres altitude in some of the farm land of the high plateau. In such areas (e.g. Setif, Algeria) the first of the warm-hot southerly sirocco winds may arrive by mid-April while frosts may occur as late as the beginning of May. Hence the growing season may be relatively short on the high plateau in Algeria. In both southern Australia and Algeria increased distance from the sea leads to lower winter minimum temperatures and higher summer maximum temperatures. Mean summer maximum temperatures are generally in the range 27-30°C in the coastal regions and 30-35°C in the interior in both Algeria and southern Australia.

From Table 3 it appears that altitudes in the Medicago areas are commonly greater in Algeria than in southern Australia. This is so. However, it is important to realize that there are substantial elevated areas in the eastern highlands of Australia (particularly the Northern Tableland and Southern Tableland areas of New South Wales) that experience cold winters. But, as the soils in these regions are acidic, the volunteer legumes are Trifolium spp. and the main sown legume is subterranean clover (Trifolium subterraneum). Normally the major farming enterprise involves sheep and beef raising on sown pastures with very little cereal
cropping. Climatic data from these colder regions is shown in Table 4.

TABLE 4

<table>
<thead>
<tr>
<th>Northern Tableland Station</th>
<th>Altitude (m)</th>
<th>Precip. (mm)</th>
<th>Max. Temp. (°C)</th>
<th>Min. Temp. (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armidale N.S.W.</td>
<td>1016</td>
<td>736</td>
<td>27.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Glen Innes</td>
<td>1073</td>
<td>796</td>
<td>26.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Guyra</td>
<td>1320</td>
<td>871</td>
<td>25.3</td>
<td>-0.7</td>
</tr>
<tr>
<td>Southern Tableland Station</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canberra A.C.T.</td>
<td>560</td>
<td>592</td>
<td>27.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Cooma N.S.W.</td>
<td>689</td>
<td>479</td>
<td>26.0</td>
<td>-1.0</td>
</tr>
<tr>
<td>Crookwell</td>
<td>887</td>
<td>881</td>
<td>26.7</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

The soils of the agricultural areas of both Algeria and South Australia are predominantly calcareous. Shallow grey and brown soils over limestone, solonized brown soils, terra rossa and rendzina soils (Stephens 1957, 1962) are common in both countries and it is these soils that support the native stands of *Medicago* in Algeria and the volunteer and sown areas of *Medicago* in southern Australia.

It is important to emphasize that edaphic factors as well as climatic factors have been of major importance in determining the natural spread of accidentally-introduced self-regenerating annual pasture legumes in southern Australia. In South Australia, following the widespread sowing of superphosphate with wheat and the topdressing of native perennial grass (*Danthonia-Stipa*) pastures in the 1920's there was a rapid spread of *Medicago* spp. on the calcareous soils of the wheat belt and of *Trifolium* spp. on the acidic soils in the higher-rainfall areas. Hence there were tens of thousands of hectares of naturalized *Medicago* spp. (especially *M. polymorpha*, *M. truncatula* and *M. minima*) and *Trifolium* spp. (especially *T. subterraneum* and *T. glomeratum*) long before there were any named cultivars of these species in Australia.

The soils at the Algerian and Australian localities listed in Table 3 are, neutral to alkaline in reaction and either developed on limestone or from highly calcareous parent material in most cases. However, the extensive siliceous sand plain country of Western Australia (including a large part of the cereal belt), despite a mild winter climate, is more suited to *Trifolium subterraneum* than to *Medicago* species because of the acidic soils. This Western Australian cereal belt environment contrasts markedly with those listed in Table 4 although *Trifolium subterraneum* is the major sown legume in both these situations.

From the foregoing it is clear that, from climatic and edaphic considerations, the coastal and inland areas of South Australia, and the inland areas of Victoria and New South Wales as exemplified in Table 3 provide the most analogous areas to those in Algeria. Certainly the high plateau areas of Algeria (e.g. Tiaret and Setif) have more severe winters than generally experienced in South Australia. However, in
both these areas of Algeria perfectly healthy *Medicago polymorpha*, *Medicago truncatula* also other *Medicago* spp. together with sundry *Trifolium* spp. survive frosts, snow and severe roadside grazing. Thus it is clear that there are existing ecotypes of both *Medicago* spp. and *Trifolium* spp. well adapted to the severe climatic and grazing conditions of the high plateau in Algeria. Confirmation of these conclusions is provided by the recent studies of Professor Conesa and Messrs. Chapot, Pilas and Adem of INA (Adem 1974).

At Setif, Algeria, in addition to the obvious success of regional ecotypes of *Medicago polymorpha* and *M. truncatula* an excellent mixed volunteer stand of *Trifolium fragiferum*, *Phalaris* sp., *Festuca* sp. and *Lolium perenne* was observed in April 1974. However, although there are obviously well-adapted regional ecotypes of a range of pasture species the relatively short and unpredictable effective rainfall season most certainly reduces the potential dry matter production below the levels obtainable in the littoral and sub-littoral areas. But this is not a feature peculiar to Algeria. It is a characteristic of all annual pasture environments where cold winters restrict winter production and dry conditions restrict spring or early summer production. It is a feature of some *Medicago* and *Trifolium* localities in southern Australia and characteristic of much of California and Chile.

With the similarity of climate and soils in Algeria and South Australia it is not surprising that there is a remarkable similarity in the weed floras of both countries. Table 5 lists some of the species (mostly native to Algeria) that are common in the cereal areas and adjacent higher-rainfall areas of Algeria and South Australia. Just as weeds from the Mediterranean Basin have become naturalized in South Australia so, too, have useful species e.g. *Medicago* spp., *Trifolium* spp. and even *Pinus halepensis*, a native of Algeria, that is the major shelter belt tree on the calcareous soils of the cereal belt of South Australia.

The similarity of the native flora in Algeria and the naturalized flora in South Australia provides good evidence for the general interchangeability of crop and pasture plants between Algeria and South Australia. However, this should not imply that regional ecotypes, or cultivars, of pasture plants selected in South Australia will necessarily perform best in Algeria - and vice versa. In fact, the preliminary studies by Adem (1974) using both Algerian ecotypes of *Medicago* and Australian cultivars of the same species indicated the superiority of some of the Algerian ecotypes. Of course this was to be expected. Furthermore, these studies highlighted the fact that there is no shortage of *Medicago* species and ecotypes in Algeria.

* In Algeria, littoral refers to the general coastal areas with warmer winters and cooler summers. Sub-littoral refers to the near-coastal regions. There is a temperature gradient from the coast to the high plateau.
TABLE 5
SOME SPECIES COMMON IN CEREAL ZONES AND ADJACENT HIGHER-RAINFALL AREAS
OF ALGERIA AND SOUTH AUSTRALIA

<table>
<thead>
<tr>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adonis annua</td>
</tr>
<tr>
<td>Asphodelus fistulosus</td>
</tr>
<tr>
<td>Avena barbata, A. fatua, A. sterilis</td>
</tr>
<tr>
<td>Brassica tournefortii</td>
</tr>
<tr>
<td>Bromus diandrus, B. hordeaceus, B. mollis, B. unioloides</td>
</tr>
<tr>
<td>Capsella bursa-pastoris</td>
</tr>
<tr>
<td>Carrichtera annua</td>
</tr>
<tr>
<td>Chenopodium album</td>
</tr>
<tr>
<td>Diplotaxis tenuifolia</td>
</tr>
<tr>
<td>Echium italicum, E. lycopsis</td>
</tr>
<tr>
<td>Fumaria officinalis</td>
</tr>
<tr>
<td>Hordeum leporinum, H. marinum</td>
</tr>
<tr>
<td>Hypochoeris glabra, H. radicata</td>
</tr>
<tr>
<td>Lolium multiflorum, L. perenne, L. rigidum, L. temulentum</td>
</tr>
<tr>
<td>Malva parviflora</td>
</tr>
<tr>
<td>Marrubium vulgare</td>
</tr>
<tr>
<td>Medicago minima, M. polymorpha, M. scutellata, M. truncatula</td>
</tr>
<tr>
<td>Melilotus indica, M. officinalis</td>
</tr>
<tr>
<td>Onopordum acaulon</td>
</tr>
<tr>
<td>Oxalis pes-caprae</td>
</tr>
<tr>
<td>Papaver hybridum, P. rhoeas</td>
</tr>
<tr>
<td>Phalaris minor, Ph. tuberosa</td>
</tr>
<tr>
<td>Plantago lanceolata, P. major</td>
</tr>
<tr>
<td>Poa annua, P. pratensis</td>
</tr>
<tr>
<td>Raphanus raphanistrum</td>
</tr>
<tr>
<td>Rapistrum rugosum</td>
</tr>
<tr>
<td>Reseda alba, R. lutea, R. luteola</td>
</tr>
<tr>
<td>Salsola kali</td>
</tr>
<tr>
<td>Silene vulgaris</td>
</tr>
<tr>
<td>Silybum marianum</td>
</tr>
<tr>
<td>Sinapis arvensis</td>
</tr>
<tr>
<td>Sisymbrium officinale, S. orientale</td>
</tr>
<tr>
<td>Trifolium fragiferum, T. glomeratum, T. resupinatum, T. tomentosum</td>
</tr>
<tr>
<td>Urtica dioica, U. urens</td>
</tr>
</tbody>
</table>

Note: With few exceptions (e.g. Oxalis pes-caprae) the above species are native to Algeria. However, none are native to Australia.
2. Land Use and Farming Practices

The comparative agricultural statistics for Algeria and South Australia are summarized in Table 6. In terms of land use capability Algeria is better placed than South Australia especially with regard to areas with mean precipitation greater than 300 mm. Furthermore a substantial area of South Australia with mean precipitation greater than 500 mm has slopes exceeding 25%. The table shows three major differences in agricultural practice: Algeria has far less sown pasture, uses far less phosphatic fertilizer, and has a far greater percentage of fallow to crop land than does South Australia. These facts are reflected in the greater livestock numbers and cereal yields in South Australia than in Algeria.

It is unfortunate that most of the recent experiments on the phosphatic fertilizer requirements of cereals in Algeria have been carried out on the Socialist Sector domains, which generally would have had substantial phosphatic fertilizer dressings in the days of French management, and which can be expected to have some reserve of residual soil phosphorus. Hence the phosphatic fertilizer requirements for crops on the generally poorer soils of farms in the Private Sector are probably being under-estimated; certainly there is little or no fertilizer residual to promote growth of volunteer Medicago spp. in the stubble (or fallow) year. Numerous examples of Medicago response to phosphatic fertilizer and phosphorus-deficient legumes were seen in the field. Even on the Oued Smar field station there was a classic example of depressed growth in April 1974 where superphosphate was missed in part of a field sowing of annual Medicago.

From the foregoing - the similarities of climate, soils and vegetation in Algeria and South Australia - many questions arise in relation to the potential for improvements in land use, agricultural practices and cereal and livestock production. While it is obvious from the statistics, and by observation in the field, that there is great potential for increasing cereal crop and livestock production in Algeria there are many constraints. These will be discussed in the next section.

Some important aspects of rural production that do not show in Table 6 concern the relative sizes of farms and of the rural labour force in Algeria and South Australia. In 1971/72 there were 29,095 rural properties in South Australia. These averaged 2240 ha but varied in size from very small market gardens to very large rangeland properties used for cattle raising in the arid zones. Furthermore, there were only 30,785 males and 8,177 females permanently employed on these properties, most being owner-operators. In the cereal-livestock zone of South Australia mean property size in 1969-70 was 898 ha; in addition to cropping 211 ha, these farms carried 1200 sheep and 13 cattle on an average of 611 ha of improved and unimproved pasture and used 40.7 metric tons of superphosphate. This contrasts with the 1970 situation in Algeria where there were 587,000 properties in the Private Sector (423,000 with < 10 ha; 147,000 with 10-50 ha and 17,000 with > 50 ha) quite apart from the 1994 larger properties in the Socialist Sector.

### TABLE 6

**SOME COMPARATIVE AGRICULTURAL STATISTICS**

<table>
<thead>
<tr>
<th></th>
<th>Algeria</th>
<th>South Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Area (ha)</strong></td>
<td>237,556,000</td>
<td>99,400,000</td>
</tr>
<tr>
<td><strong>Distribution of Land By Rainfall</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 600 mm</td>
<td>5,081,000(^{(1)})</td>
<td>1,082,000</td>
</tr>
<tr>
<td>500-600 mm</td>
<td>1,756,000</td>
<td>2,165,000</td>
</tr>
<tr>
<td>400-500 mm</td>
<td>4,538,000</td>
<td>4,428,000</td>
</tr>
<tr>
<td>300-400 mm</td>
<td>7,558,000</td>
<td>3,051,000</td>
</tr>
<tr>
<td>&lt; 300 mm</td>
<td>218,623,000</td>
<td>87,674,000</td>
</tr>
<tr>
<td><strong>Land Used for Agriculture (ha) (1971/72)</strong></td>
<td>42,449,000</td>
<td>65,146,000</td>
</tr>
<tr>
<td>Cereals for grain (ha)</td>
<td>3,228,000(^{(2)})</td>
<td>2,041,000</td>
</tr>
<tr>
<td>Other annual crops (ha)</td>
<td>313,000</td>
<td>181,000</td>
</tr>
<tr>
<td>Fallow (ha)</td>
<td>2,707,000</td>
<td>402,000</td>
</tr>
<tr>
<td>Vineyards (ha)</td>
<td>300,000</td>
<td>29,000</td>
</tr>
<tr>
<td>Orchards and Vegetables (ha)</td>
<td>252,000</td>
<td>27,000</td>
</tr>
<tr>
<td>Pasture (ha)</td>
<td>35,000</td>
<td>3,194,000</td>
</tr>
<tr>
<td>Rangeland (ha)</td>
<td>34,345,000(^{(4)})</td>
<td>59,272,000</td>
</tr>
<tr>
<td>Unproductive farm lands (ha)</td>
<td>1,269,000</td>
<td>tr</td>
</tr>
<tr>
<td><strong>Superphosphate Used (Means 1966/67-1971/72)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crops (tonnes P(_2)O(_5))</td>
<td>31,360</td>
<td>60,968</td>
</tr>
<tr>
<td>Pastures (tonnes P(_2)O(_5))</td>
<td>tr</td>
<td>59,444</td>
</tr>
<tr>
<td><strong>Cereal Production (Means 1961-72)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat harvested (ha)</td>
<td>2,035,200</td>
<td>1,165,600</td>
</tr>
<tr>
<td>Wheat yield (kg/ha)</td>
<td>624</td>
<td>1,139</td>
</tr>
<tr>
<td>Barley harvested (ha)</td>
<td>728,900</td>
<td>561,000</td>
</tr>
<tr>
<td>Barley yield (kg/ha)</td>
<td>610</td>
<td>1,131</td>
</tr>
<tr>
<td><strong>Livestock (Mean head 1970-72)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheep</td>
<td>8,357,000</td>
<td>18,961,000</td>
</tr>
<tr>
<td>Cattle</td>
<td>864,000</td>
<td>1,239,000</td>
</tr>
</tbody>
</table>

(1) Includes 1,335,000 ha with slope > 25%

(2) Includes c. 1 million ha in marginal steppe

(3) Includes cereals for hay and green forage crops

(4) Includes c. 20 million ha of steppe

**Source:** Statistique Agricole (MARA) and Algeria in Numbers, 1962-72. Statistical Register of South Australia 1971-72, Commonwealth Bureau Census and Statistics.
III. CONSTRAINTS TO CEREAL AND LIVESTOCK PRODUCTION: THE NEED FOR CHANGED METHODS

1. Soil Erosion

The irreversible damage caused by wind and water erosion is a major constraint to cereal crop and livestock production in Algeria (Plate 2). Desert encroachment in the steppe is a direct result of cultivation and overgrazing (Plate 3). The only reliable method of preserving the productivity of the 20 million hectares of steppe is to reduce the livestock numbers and human population on this area (Skilbeck et al 1973, Carter 1974a). This can be done by providing alternative grazing areas through greatly increasing pasture and forage production in the cereal-crop zone and higher-rainfall areas of Algeria.

Although it is ecologically possible to regenerate the steppe it is generally economically impracticable to do so - especially on a large scale. However, providing there is still a reserve of seed in or on the soil surface, furrowing or pitting the soil will allow concentration of water and encourage regeneration. Alternatively, seed of arid zone genera e.g. Atriplex and Kochia can be sown in the furrows or pits to expedite the process of regeneration. It is essential that there be complete exclusion of grazing animals during this regeneration process.

The very serious sheet, rill and gully erosion in the cereal croplands is a matter of grave concern. Erosion is reducing land resources, preventing access to fields and permanently impairing productivity as well as causing problems of flooding, siltation of reservoirs and irrigation systems. Clearly, expensive civil engineering structures can help limit runoff and minimise flooding but the only reliable long-term solution lies in adoption of well-known soil conservation practices: contour furrowing, contour banking and contour cultivation together with the provision of grassed waterways for safe removal of surplus water. Areas that are far too steep for safe cereal cropping (e.g. 80% and even 100% slopes are used in Algeria) should be sown to pasture* and regularly fertilized to assist in the overall programme of watershed management.

2. Soil Structure, Fallowing and Deep Ploughing

The medium-heavy texture, the loss of top soil through erosion, the long history of cropping, the use of long bare summer fallows and the practice of deep ploughing all contribute to the generally poor structure of Algerian cropping soils.

In Algeria, and in other North African and Near East countries, fallowing in the two-course rotation (fallow-cereal-fallow-cereal --–) undoubtedly evolved in the days of draught animals to spread the tillage work-load, to ensure that land was prepared well in advance of sowing to allow adequate time for preparing a seedbed and sowing the crop, to eliminate weeds, to allow accumulation of soil water in deeper soils with reasonable water-holding capacity and to accumulate some soil nitrogen for

* Mixed annual and perennial grasses and legumes, the species depending on the particular site and location.
the subsequent crop. However, with extensive mechanization of tillage and sowing operations, the need for early soil preparation has diminished though it is certainly convenient to have some prepared fallow to allow a greater spread of sowing and reaping operations. Furthermore, on most of the shallow soils in the Algerian cereal-producing areas, soil moisture storage through summer is negligible.

It should be noted that the term "jachere" has a wider meaning in Algeria than does "fallow" in Australia. The jachere embraces stubble land which, following the traditional hard grazing, may be:

1. ploughed in winter for a long fallow
2. allowed to produce volunteer pasture growth before ploughing in spring or
3. have a temporary forage crop sown into the stubble to enhance feed supply prior to ploughing in spring-autumn.

There appears to be no clear scientific basis for the widespread farming practice of deep ploughing in preparation of the fallow in the cereal lands of Algeria (and elsewhere in North Africa, the Near East and Spain). The following would seem to be the most logical explanation. After centuries of tillage, the structure of most of the Algerian soils is very poor: the generally heavy soil texture and low levels of soil organic matter have contributed to this problem of poor soil structure. Thus deep ploughing (commonly 25-30 cm) with consequent rough soil surface allows temporary storage of water in/on the soil surface thus allowing time for infiltration. However, the deep ploughing certainly contributes to poor soil structure because the slowness of the deep-ploughing operation means that soils are often ploughed when outside the optimum range of soil moisture. Furthermore, the deep ploughing has eliminated, and will continue to eliminate, the valuable self-regenerating annual pasture legumes mainly *Medicago* spp. from the cereal lands. And, of course, the deep ploughing is excessively expensive. Early (spring) ploughing prevents seed set by these legumes and late (autumn) deep ploughing after seed maturity eliminates the legumes through deep burial of the seed. While the annual *Medicago* spp. have a high percentage of hard seed which is softened by burial in the soil, ploughing and subsequent tillage must aim at keeping a high proportion of the seed sufficiently near the soil surface to allow emergence of seedlings.

The immediate discontinuance of deep ploughing and a marked reduction in the area of long fallow is essential for the encouragement of volunteer annual self-regenerating *Medicago* spp. or the management of sown *Medicago* spp. in Algeria. However, in the short term, until soil organic matter levels and consequent soil structure and infiltration have been improved through use of *Medicago* spp., some runoff of water and erosion is likely to continue in those areas in need of contour banking. With regard to reduction of the fallow it seems reasonable to eliminate the long fallow and greatly increase livestock feed production on two million hectares in Algeria (Table 6). A ploughing and general tillage depth not exceeding 8-10 cm should suffice in most cereal areas of Algeria.

In summary, the discontinuance of deep ploughing, the replacement of the long fallow, and the transformation of the poorly-producing stubble land by sowing and/or

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* See, for example, Kohn, Storrier and Cuthbertson (1966)
Serious soil erosion in hilly country of Algeria demands urgent control measures to save valuable crop and pasture land, to minimise flooding and prevent siltation of reservoirs and irrigation systems. Cropping will need to be precluded from the steepest areas and these areas sown to pasture.

(Photographs: Algeria, April 1974)
Overgrazing of hill country, cropping and overgrazing in the steppe, and the traditional separate ownership of land and livestock contribute to declining grazing and crop-land resources in Algeria. Encouragement of self-regenerating annual Medicago pastures through reduced depth of tillage and use of more superphosphate, and elimination of some two million hectares of long fallow, will greatly enhance pasture and forage crop production in the cereal zone and thus allow reduced grazing pressure with consequent reduction in erosion on hill country and steppe.

(Photographs : Algeria, April 1974)
encouraging existing Medicago spp. will lead to increased cereal and livestock production and certainly help to reduce erosion in Algeria. The symbiotic nitrogen fixation—approx. 3 or 4 kg N/kg P₂O₅ applied—(Carter 1974a) will more than offset the cost of the extra superphosphate needed to promote good growth of Medicago while the savings in cost by adopting new shallow tillage practices will more than cover the cost of purchase and sowing of Medicago seeds. While these changes can be effected without altering the basic rotation involving cropping in alternate years, there is a great need for improved tillage and sowing machinery.

3. Tillage and Sowing Implements and Equipment

(a) General

The existing range of tillage and sowing implements used in Algeria is quite unsuitable for the soil conditions, topography and farm sizes involved. Not only are these implements (imported mainly from Europe) structurally inadequate leading to excessive wear and tear and breakages but also the lack of standardisation on particular makes or models leads to confusion by operators and makes for very expensive maintenance through the need for excessive stocks of spare parts.

There is no real evidence in support of the general need for deep ploughing in Algeria yet almost all initial ploughing for fallows in the cereal belt is deep (commonly 25-30 cm) and the mouldboard ploughs and most of the disc ploughs in common use are designed for deep ploughing only. The small width of the ploughs (commonly mounted or semi-mounted on three-point linkage) results in slow, expensive and rough ploughing. This inevitably leads to rough seedbed preparation. Furthermore, the offset disc cultivator, especially when used without depth-control wheels, often aggravates the problem of levelling the seedbed by "stirring" and ridging the seedbed rather than "raking" and levelling the seedbed as can be ensured by using a wheeled, tyned implement. Well-timed, shallow cultivations with a tyned implement not only ensures germination, emergence and destruction of weeds but also forms an ideal seedbed (Carter and Saunders 1970).

In Algeria, where timing of tillage for seedbed preparation and sowing operations is so important in relation to soil moisture, the size, design and ruggedness of implements is critical to ensure that large areas are covered rapidly, effectively and cheaply. For tillage and sowing implements to be useful and versatile in Algeria these must have five basic features as follows:

1. Stump-jump (SJ) principle - to allow passage over solid obstacles without damage
2. Clearance - to handle trash and allow passage over solid obstacles
3. Strength - for long life and minimal maintenance
4. Wheeled - for proper depth control and to provide a levelling action
5. Width - for rapidity of operation and to provide a levelling action.

The SJ principle is standard on Australian ploughs, scarifiers, seed and fertilizer drills (or combines) where under-frame clearance is generally 45-50 cm and disc or tyned clearance 30-45 cm.
(b) Ploughs

No ploughs incorporating an effective stump-jump (SJ) principle have been seen in Algeria, yet these have been standard in Australia since the turn of the century, soon after R.B. and C.H. Smith invented their first SJ mouldboard plough in 1876, in South Australia. The use of these SJ ploughs would change the whole concept of what was, in fact, arable land in many areas of Algeria. These ploughs (both mouldboard and disc) have the advantage of being able to pass over immovable objects (such as deep-seated rocks) without damage to the plough. The various safety devices on the fixed disc and mouldboard ploughs that are at present used in Algeria are not a satisfactory substitute for the SJ principle.

The larger Australian disc ploughs have an effective solid object clearance of about 45 cm but have the strength and undercut to oust very large tree stumps and stones. Some impression of the type of timber that can be ploughed under by the most rugged of these ploughs is seen in Plate 4, A and B. The approximate Drawbar Horse-power required for this plough is of the order of 5 D.B.H.P. per furrow. Large tractors normally draw two of these ploughs in tandem.

Australian disc ploughs are made in a range of sizes (up to 5 m cut) to match tractor size and farm needs. A common type in the cereal belt of South Australia is shown in Plate 5, A. These would have tremendous advantages in Algeria for:

1. Reducing costs of land preparation - the larger ploughs would have no difficulty in going straight through and turning under shrubby thickets
2. Rapid, shallow, even ploughing following autumn rains

Mouldboard ploughs are required for best results in some of the wetter areas where perennial weedy species form a turf and where it is necessary to completely turn the sod to ensure adequate kill of the existing cover, prior to sowing crop or pasture. In these situations an initial mouldboard ploughing may need to be 15-20 cm deep, or even more.

(c) Scarifiers and Harrows

Scarifiers of the rigid-tyne, spring-release type (Plate 5, B) with cutting width of up to 5 m (and also light-draught cultivators covering 10 m or more) could greatly expedite seedbed preparation in Algeria. These wheeled, wide, tillage implements could improve timing of tillage operations and generally assist in levelling many of the rough paddocks in Algeria.

The levelling action of the scarifiers and cultivators could be further helped by harrows of various weights, rows and widths. There is a need for mainly the hinged-joint (SJ) types of harrow in Algeria. The various folding types (manual or hydraulic), complete with wheeled harrow-bars for proper control of action and depth, as manufactured in Australia would be very useful for seedbed preparation in Algeria.
Photographs A-D show a three-stage ploughing, harrowing and sowing operation (with disc-seeder) in a rough clearing programme based on firing of the cereal stubble to control regrowth of the scrub prior to further tillage and sowing down pasture.

Photographs E-G show a finger-wheel, side-delivery stump and stone rake while photograph H shows a dump-type stump and stone rake. Both types of rake are used for clearing debris from the soil during the clearing programme.

(Photographs: Original prints A-D ex John Shearer and Sons Ltd., Kilkenny, S. Aust E-H ex Horwood Bagshaw Ltd., Mile End, S. Aust.)
Typical South Australian farm implements. The stump-jump mechanism functions through compression of a strong spiral spring in each of these three implements though springtyne cultivators are common, especially in the wider, lighter-draught implements. Note the wheels for depth control, size of implements and the shallow tillage. The spring release combine shown with typical light trailing harrows has three optional, easily-changed undercarriages, viz. spring tyne, trash discer and disc drill undercarriages.

(Photographs: Original prints ex John Shearer and Sons Ltd., Kilkenny, S. Aust.)
(d) The Chain and the Slab Leveller

The use of heavy chain in a single loop, or multiple loops, or the combination of loops and rails (the size, length, number of loops, width of pass, and weight of chain is matched to drawbar horsepower availability) to give stability and extra weight between two tractors is a cheap and effective method of knocking down timber and brush in the clearing programme, or for levelling and compacting ploughed land. The weight of the chain and the angle of pass determines both its knock-down value and rowing effect. Typical chain rigs are shown in Figure 2.

The slab leveller is a cheap and effective aid to levelling and compacting soil prior to sowing to assist in achieving a very smooth surface for ideal sowing and to fill holes and thus prevent waterlogging in micro-depressions. It is a useful aid in preparing land for seed harvesting. A typical slab leveller is shown in Figure 2.

(e) Sowing Implements

The various disc and tyned drills imported from Europe to Algeria are generally unsuitable because of one or more of the following defects:

(1) the ground wheels are too small for fast sowing of any but very level ground,
(2) insufficient clearance for trash or for use on non-arable soils: SJ mechanism absent or inadequate,
(3) insufficient strength for long, trouble-free service.

For rapid sowing to ensure correct timing in relation to rains or soil moisture condition and for use under rough seedbed conditions, e.g. eroded soil or soil with loose stones or immovable objects at the surface, then two essential features are firstly large wheels and secondly good clearance. These features are possessed by the Australian sowing machinery but not incorporated into sowing machinery in present use in Algeria.

There are five separate sowing implements commonly used in Australia that have direct applicability to various zones in Algeria.

(1) Disc seeder (combined disc-plough and seeder - see Plate 4, D)
(2) Trash cultiseeder (combined disc cultivator and drill)
(3) Combine (combined tyned cultivator and drill - see Plate 5, C)
(4) Disc sod seeder (see Plate 1)
(5) Disc drill.

The disc seeder is used for very rough sowing conditions, e.g. in land clearing.

The trash cultiseeder is a rough-sowing machine for cultivating trash, e.g. cereal stubble and simultaneous sowing of cereal or pasture seeds.

The Australian-type combine (combined cultivator and drill - see Plate 5) is a multi-purpose machine for cultivating, for sowing cereal and/or pasture seeds (various band-seeding attachments are available in addition to the conventional small-seeds box) as well as for sowing or spreading fertilizer.
The disc sod seeder (see Plate 1) is an ideal machine for penetration of either sod-bound soil, dense turf, or hard soil with minimum disturbance to the soil surface.

The disc drill is a lighter machine designed for precision sowing on prepared soil.

The latter three implements could prove of tremendous benefit in Algeria for both cereal and pasture sowing. Sizes are matched to tractor size: 3 point-linkage sowing machinery is available in the smaller sizes. Trailing harrows are standard. Apart from the disc seeder these machines have general application and specific uses for sowing on various types of land. In each case, large wheels and good ground clearance are an important feature to buffer against rough soil conditions and enable large areas to be covered free of mechanical trouble. These machines are made in sizes up to 26-row, i.e. 5 metres coverage (as are also the scarifiers and disc ploughs, Plate 5) and, with a suitably matched wheeled tractor and trailer harrows it is practicable to sow 50 ha in a 10-12 hour day under good conditions. Machinery of the type of the new 40-row centrally-hinged Shearer "Wideseeders" have even greater potential for timely cultivation and/or sowing of large areas. Of course, in the case of all this sowing and tillage equipment, multiple hitching will increase potential coverage/hour.

As sowing implements are imported into Algeria it is important that multi-purpose machines are brought in. These Australian sowing machines may be used for sowing of pasture seed, cereal grain and fertilizer (concurrently if required, from three separate hoxes). Any one of these three sowing machines is ideal for top-dressing the pasture with fertilizer (money invested in a separate fertilizer dropper is wasted). Furthermore, the Australian combine can be used separately for normal cultivation for weed destruction. These are available also with disc-drill conversion, i.e. the same chassis is used for both the tyned and disc under carriages.

In general, the best of the Australian sowing implements are extremely adaptable, robust and suitable for several separate operations. These machines are definitely superior to anything seen in Algeria and could aid the cereal crop and pasture production programmes and reduce costs because of greater efficiency. Sowing implements of North American origin, while possessing many desirable features, have not comparable stump-jump mechanisms to those on good Australian implements. This stump-jump feature is essential in most cereal areas of Algeria.

With regard to these multi-purpose cultivating and sowing implements (and the same applies to the ploughs and scarifiers) it is most important that managers and operators receive adequate on-job training in the proper role and function, and correct use and maintenance, of this equipment to ensure the best performance at minimum cost.
Typical chain rigs for clearing trees or shrubs or for the preliminary levelling and consolidation of newly-ploughed or ripped land.

A typical slab leveller designed for use with a medium-powered tractor.
In Algeria many good areas of volunteer annual Medicago occur where land has remained undisturbed or where tillage has been shallow during the cropping years.

Upper photo: Well-grazed volunteer pasture of *M. polymorpha* and *M. truncatula* in the Constantine area.

Middle photo: Well-grazed volunteer medic pasture (mainly *M. truncatula* and *M. polymorpha*) on roadside contiguous to stubble land near Tiaret.

Lower photo: Typical cereal stubble area on land with a history of deep ploughing on site immediately adjacent to site of middle photo (above).

(Photographs: Algeria, April 1974)
4. Weed Problems

Weeds in the cereal-crop areas of Algeria cause substantial losses in cereal production and increased costs of production through extensive herbicide spraying. In the stubble year the unavailability of livestock and lack of fencing preclude timely, high-density stocking hence weedy pastures are a common sign of poor grazing management. Weeds such as Sinapsis arvensis set seed under these conditions and become troublesome in the following cereal crop.

Many of the weed problems in cereal crops are directly related to tillage practice. Cultivations are often poorly timed (through lack of suitable wide tillage implements) and the control of tillage depth is inadequate. More attention is needed to ensure that either tillage depth is constant or that there is a progressive reduction in the depth of consecutive cultivations in preparation of the seedbed to ensure that fresh weed seeds are not brought near to the soil surface so permitting germination and emergence.

More suitable tillage implements, more timely cultivations and more dense, grazed Medicago pastures (to help reduce weeds through grazing and plant competition) will greatly assist in the control of most weeds. Until these changes can be effected the herbicide spraying procedures resulting from the investigations undertaken in the Cereals Project (Algeria), and elsewhere, must continue to minimise losses in the production of cereals.

5. The Quality and Productivity of Volunteer Pastures

The volunteer (or spontaneous) pastures of Algeria vary from excellent mixed grass-legume pastures in some undisturbed sites in the higher-rainfall areas (e.g. Bordj Menaiel, Dellys, Tizi Ouzou) to extremely poor in the stubble year following the cereal crop. As mentioned previously, the traditional early and/or deep ploughing has almost eliminated Medicago from most crop areas yet in the contiguous roadside Medicago polymorpha and M. truncatula are particularly widespread (Plate 6). Medicago polymorpha was found at each site and M. truncatula at approximately 75% of sites in a total of 400 field and roadside inspections throughout Algeria from the coastal regions to the high plateau and beyond to the northern limits of the steppe. Medicago scutellata, M. orbicularis and M. ciliaris are also widespread on the road-sides of the cereal belt.

Table 7 summarizes data from Levy Point Quadrat Surveys in three typical sites where deep ploughing was used in preparation for the cereal crop and shows clearly the poor density (and productivity) of volunteer pasture after the cereal crop relative to the contiguous unploughed roadside\(^*\) The fact that most areas of good volunteer medic occur on shallow (often skeletal) soils where shallow tillage is obligatory provides further convincing evidence of the advantage of shallow tillage to perpetuate the annual Medicago species. As a group these have a high percentage

\(^*\) These roadside areas were immediately adjacent to and on the same level as the cropped area and quite remote from depressions receiving runoff water from the road.
of hard seed which is softened by burial in the soil following tillage for the cereal crop. However, if the seed is buried too deeply these seedlings are unable to emerge. Seed size has an important bearing on ability to emerge especially in heavy-textured soils (clay loams and clays).

### TABLE 7

**TYPICAL EXAMPLES OF PLANT DENSITY, BOTANICAL COMPOSITION AND GROUND COVER ON STUBBLE AND CONTIGUOUS ROADSIDE**  
(Levy Point Quadrat Data, Algeria, April 1974)

<table>
<thead>
<tr>
<th>Site</th>
<th>Vegetative Hits per 100 points</th>
<th>Percentage Overlapping Cover*</th>
<th>Percentage Bare Ground</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Legume</td>
<td>Grass</td>
</tr>
<tr>
<td><strong>Near Oued Taria</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(600 m) Stubble</td>
<td>36</td>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td>Roadside</td>
<td>100</td>
<td>28</td>
<td>34</td>
</tr>
<tr>
<td><strong>Near Berrouagha</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(800 m) Stubble</td>
<td>41</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>Roadside</td>
<td>159</td>
<td>11</td>
<td>46</td>
</tr>
<tr>
<td><strong>Near Tiaret</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1000 m) Stubble</td>
<td>17</td>
<td>35</td>
<td>53</td>
</tr>
<tr>
<td>Roadside</td>
<td>165</td>
<td>38</td>
<td>55</td>
</tr>
</tbody>
</table>

*Note: Legume comprised mainly *Medicago* and *Trifolium*.

*See Levy and Madden (1933)*

In contrast to the above data, a stubble site on skeletal soil over limestone near Constantine (660 m) had a good mixed stand of *M. polymorpha*, *M. truncatula* and *M. minima* with a few *Trifolium* spp. On April 8, 1974 the vegetative hits per 100 points totalled 75, while legumes, grass, and other spp. contributed 27%, 66% and 5% respectively to percentage overlapping cover. Bare ground totalled 41%, including bare limestone.

Pre-requisites for the success of an annual *Medicago*-cereal crop rotation will be first the encouragement of existing volunteer medic or the sowing of either local ecotypes or imported cultivars of annual *Medicago* species to ensure a complete cover of *Medicago* and good seed reserves before ploughing, secondly the reduction of depth of ploughing (and other tillage) to a maximum of 8-10 cm, and thirdly the use of increased quantities of soluble phosphatic fertilizer to encourage the establishment and productivity of the *Medicago* species.

#### 6. Inadequate Crop-Livestock Integration

The traditional dichotomy in ownership of land and livestock in Algeria makes it difficult to effect rapid changes with respect to integration of crop and livestock production. However, the current nomadic and transhumant livestock management
systems contribute to overgrazing and erosion in most places and to undergrazing with consequent weed problems in other areas. These factors act as constraints to both cereal crop and livestock production.

There is a clear need to reduce grazing pressure on the steppe and this can be achieved by providing alternative grazing for flocks and herds in the cereal and higher-rainfall zones just as is the case in South Australia where the sheep and cattle industry is stratified as follows:

1. Arid and Semi-arid Pastoral Land (125-250 mm mean rainfall)
2. Cereal-Livestock Farming Land (250-500 mm mean rainfall)
3. Higher-rainfall Grazing Land (> 500 mm mean rainfall)

There is a well-established annual movement of surplus young wethers* and older Merino ewes from the pastoral land (= Algerian steppe) to the other two zones to allow fattening prior to slaughter, for wool production or, in the case of the old ewes, to rear another one or two lambs in a more favourable environment with more assured feed supply. Similarly, store cattle are transported (by rail and road) from the pastoral land to the cereal and Higher-rainfall areas for fattening prior to slaughter. This is an efficient system of integration: it suits landholders in all three zones and ensures conservative stocking in the arid and semi-arid zone. It has direct relevance to the situation in Algeria.

7. Training, Research and Extension

The shortage of skilled and experienced personnel at all levels in agriculture is a serious constraint to production. While there are extensive training courses for technicians at certificate and diploma level, and ITA (Mostaganem) and INA (El Harrach) are both training graduates, there is an urgent need for this training to have a broader practical base. Far too many teachers, lecturers and professors at these various training institutions have never travelled beyond Europe. Their training generally has been based on European traditions, therefore it is inevitable that present-day students get a disproportionate emphasis on European-type agriculture. While such European visiting, training and teaching may be quite relevant to viticultural, horticultural and vegetable production it is certainly not relevant to the major problems of cereal and livestock production in Algeria. Therefore, it is important that agricultural education in Algeria become more broadly based.

There needs to be a substantial increase in the numbers of agricultural books and periodicals published in English in the libraries of both ITA (Mostaganem) and INA (El Harrach). In fact, there would be considerable merit in teaching some coursework in English at both of these establishments.

Short courses in the soil, plant and animal sciences given in Algeria by visiting professors and agricultural research scientists could greatly help to broaden the interests and experiences of participants and help improve the quality and

* Castrated male sheep
relevance of agricultural research: there are too many examples of research which is irrelevant to existing problems in Algeria.

More opportunities need to be provided for agricultural-teachers, lecturers, professors, research workers and administrators to see agricultural practices and land use, and to participate in training courses, in relevant overseas countries e.g. southern Australia, north western United States. Well-organized study tours could do much to broaden experience and provide incentive for improvement in agricultural production in Algeria.

Agricultural research in Algeria should be confined to relevant and urgent production research amenable to both statistical and economic analysis. With a complete and reliable research base then extension information becomes much more acceptable and changes in agricultural practices achieved more rapidly. However, it must be clearly recognized that, with a better educated farming community, most decisions (e.g. date of sowing Medicago or wheat) must be made by the farmer (or manager) on the spot because he knows the local conditions of soils and weather and the associated risks of sowing early, sowing late, etc. No amount of extension can replace the need for local decision-making.

The training, research and extension programme of the Cereals Project in Algeria is an excellent example of a cooperative effort by National (MARA), bilateral (CIMMYT, CCCE) and multilateral (FAO/UNDP) agencies. The research and training programmes offered by CIMMYT in Algeria, Mexico and elsewhere, and similar aid by CCCE and FAO/UNDP are greatly assisting in many aspects of cereal production. However, in Algeria, cereal production cannot be divorced from livestock production so there is an urgent need for concurrent research in pasture and forage crop production, and the integration of crop production and livestock production. Hopefully, the proposed International Research Centre for Mediterranean Agriculture will play a leading role in the promotion of research related to the ecology, production, management and utilization of pastures and forage crops, and crop-livestock integration, in Algeria as well as other North African and Near East countries.

It is most important that carefully chosen Ing. Agron. graduates from Algeria be given the opportunity to undertake advanced training (to Masters and Ph.D. levels) at selected overseas Universities in those disciplines of most relevance to increasing both cereal and livestock production in Algeria. These persons could then be expected to lead research groups in areas such as pasture ecology and production; pasture management and utilization; rangeland ecology and management; fodder conservation and supplementary feeding; livestock production; tillage practice and soil conservation; soil fertility and fertilizer practice; plant pathology and nematology; entomology; weed control.

Finally, there should be an amalgamation of all research related to plant production and livestock production in Algeria into a National Institute of Agricultural Research. This would minimise duplication of facilities and ensure proper coordination of research activities e.g. tillage practice and fertilizer use is of major importance to cereal production and to pasture production which in turn is the major determinant of livestock production.
IV. THE POTENTIAL ROLE OF LEGUMES IN ALGERIAN AGRICULTURE

1. General

While beans, chickpeas, lentils and other legumes for human food will continue to be important and probably increase in importance there is clear evidence of the need for, and potential value of, pasture and forage legumes in rotation with cereals in Algeria. The close similarities of Algeria and South Australia with respect to calcareous soils, climate and weed floras in the cereal belt have been mentioned in Section II and there are no technical reasons why pasture and forage legumes should not fulfill the same role in raising cereal and livestock production in Algeria as in South Australia (see, for example, French, Matheson and Clarke 1968).

Although Medicago truncatula, M. polymorpha and M. minima have become naturalized in the marginal cereal-growing land and in fact extend into the shrub steppe (Atriplex spp. and Kochia spp.) communities of South Australia, just as M. truncatula, M. laciniata and M. minima occur in the Algerian steppe, in South Australia most of the sown pastures are within the Mediterranean climatic zone with rainfall exceeding 300 mm (10.9% of the total area); in most of the State pasture improvement is restricted by low rainfall. In these sown pastures, annual species (and to a lesser extent, perennial species) of Mediterranean origin are the most successful. The main sown legumes are Trifolium subterraneum, Medicago truncatula, M. littoralis, M. scutellata and M. sativa with lesser areas of Trifolium fragiferum and T. repens. The main sown grasses are Lolium rigidum and Phalaris tuberosa with lesser areas of Lolium perenne and Dactylis glomerata. In general, perennial pasture species of northern European origin are of limited use except under irrigation or in areas with a rainfall season of 8 months or more. Annual legumes and grasses e.g. Medicago polymorpha, M. minima, Bromus spp. and Hordeum spp. are common volunteer (spontaneous) species in the sown pastures.

In simplified terms, the cereal and livestock lands of Algeria may be stratified into the steppe zone (livestock breeding area), cereal-livestock zone and the higher-rainfall grazing areas. These are analogous to the zones in South Australia (see III, 6).

In South Australia, as elsewhere in Australia, there has been a deliberate policy of reducing both livestock numbers and human population in the arid and semi-arid areas. There has been a gradual retraction from the pastoral zone (= Algerian steppe) and dry marginal cereal growing areas to areas with more assured rainfall. Concurrently there has been wide adoption of the practice of using soluble phosphatic fertilizer (generally single superphosphate) to stimulate the production of self-regenerating annual pasture legumes which has led to dramatic increases in livestock numbers, increased crop production and a close integration of cereal crop and livestock production. In South Australia, symbiotic nitrogen fixation is as follows:

The net increment of soil nitrogen resulting from symbiotic nitrogen fixation varies with the productivity of the leguminous sward but a fair estimate of a mean value is 70 kg N/ha/annum or 3-4 kg N/kg P₂O₅ applied. The annual value of
incremental soil nitrogen from the grazed leguminous pastures, based mainly on *Trifolium subterraneum* and *Medicago truncatula* in South Australia, and assuming 30 €/kg N, is US $77 million. In the cereal belt, this nitrogen is utilized by *Trifolium subterraneum* and *Medicago truncatula* in South Australia, and assuming 30 €/kg N, is US $77 million. In the cereal belt, this nitrogen is utilized by crops in the rotation, e.g.

(1) Medic - wheat - medic - wheat
(2) Medic - barley - medic - barley (short rotation: medic not re-sown)
(3) Medic - barley - barley - medic
(4) Sub-clover - sub-clover - sub-clover - wheat - barley - barley (long rotation: sub-clover generally re-sown)

In the higher rainfall regions, the legume nitrogen is utilized by sown or volunteer pasture grasses or non-leguminous weeds.

Although native *Medicago truncatula*, *M. minima* and *M. lacineata* occur in the Algerian steppe there is no merit in attempting to improve these low rainfall steppe areas by sowing *Medicago* and applying phosphatic fertilizer. Improvement of the steppe by conservative stocking and the use of furrowing and pitting (see III,1.) is a more reasonable approach. In South Australia the lower limit for profitable sowing of *Medicago* spp. (generally *M. littoralis*) approximates 300 mm mean annual rainfall. In Algeria, at least until abundant seed is available of well-adapted local ecotypes, the 350 mm mean annual rainfall isohyet should be adopted as the lower limit for sowing *Medicago*. Thus the same isohyets as for reasonably successful cereal cropping in both Algeria and South Australia should be the guide to the lower limit for reasonably successful *Medicago* sowings. It is quite unrealistic to expect to increase livestock production from the steppe. At best, the herbage productivity of the steppe can be maintained or even slightly improved leading to stabilization of livestock numbers providing there is an assured annual offtake of non-productive animals. In other words minimum animal numbers each with maximum productivity should be the aim on the steppe in Algeria.

Hence the main investment in pasture and forage crop improvement must be concentrated in the traditional cereal-growing areas ranging from the coastal regions to the high plateau and also in the higher-rainfall hill country along the northern coastal region of Algeria between Algiers and Annaba and beyond to the Tunisian border.

2. The Potential For Increasing Livestock Production in Algeria

The cereal-crop zone is the area of most immediate concern in which there is an urgent need for inclusion of *Medicago* spp. in the rotation to improve soil organic matter levels and structure, improve soil nitrogen levels for the subsequent cereal crop, provide much-needed, nutritious, green and dry feed for the flocks and herds and directly and indirectly help in controlling crop weeds.

The main limitations to livestock production in the cereal-crop zone of Algeria are the existing deficits in quantity and quality of feed. The greatest potential for improving livestock feed supply lies in improving the productivity of existing volunteer pastures in the cereal crop stubbles by use of increased quantities of
phosphatic fertilizer and the sowing of seed of self-regenerating annual Medicago species to replace the conventional fallow. Until the Medicago is well established with adequate reserves of hard seed, ploughing for the subsequent crop must be delayed until after maturity of the Medicago seed.

Once the feed supply is assured further increase in productivity per head from existing livestock is possible through improved attention to disease control and general husbandry practices. Furthermore, increased rates of stocking might be used to advantage on well-established pastures to improve output of livestock product per unit area and to assist in pasture management (e.g. legumes depressed by over-grown grass resulting from lax grazing).

There is insufficient data on which to base predictions on the potential productivity of well-established annual Medicago pastures used in rotation with cereal crops in Algeria. However, Australian experience would suggest that the dry matter yields as shown in Table 8 are quite feasible. Likewise it is difficult to derive a realistic mean for existing productivity of the stubble areas prior to fallowing. Obviously many of these stubble areas yield only 100-500 kg DM/ha before fallowing. On the other hand some good stands of spontaneous Medicago (e.g. Oran, Bouira, Constantine) would certainly yield 4000-6000 kg DM/ha unless fallowed early. With superphosphate applications the yield would be much greater. Having regard to the generally poor legume status of most stubbles, particularly on the high plateau, a potential mean increase in the cereal crop zone of c. 4000 kg DM/ha seems a reasonable goal. The existing and potential productivity of the stubble areas in the three zones might then be as shown in Table 8.

**TABLE 8**

**ESTIMATES OF POTENTIAL IMPROVEMENT IN PASTURE PRODUCTIVITY**

**BASED ON USE OF MEDICAGO SPP. AND SUPERPHOSPHATE**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Existing Range of Production (kg DM/ha)</th>
<th>Potential Range of Production (kg DM/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal</td>
<td>4000 - 6000</td>
<td>8000 - 12000</td>
</tr>
<tr>
<td>Intermediate</td>
<td>2000 - 4000</td>
<td>6000 - 9000</td>
</tr>
<tr>
<td>High Plateau</td>
<td>1000 - 2000*</td>
<td>4000 - 6000</td>
</tr>
</tbody>
</table>

* Includes sown forage crops

Assuming that there is a retraction from the driest cereal areas and that productive annual Medicago pastures replace various kinds of fallow on 2.5 million hectares such a Medicago-cereal rotation in Algeria should provide:

(1) An increase of c. 10 million metric tons (DM) of high quality green pasture, dry pasture or hay which would feed an extra 10 million ewe equivalents per year.

(2) A soil nitrogen increment from the grazed Medicago pastures of about 60 kg/ha. If valued at 30 $/kg N this represents a saving of US $45 million per year.

(3) Increased soil organic matter levels, improved soil structure and better infiltration of water.

(4) Control of weeds by direct competition with sown pasture and through grazing by sheep and other livestock. [Assume 75% pasture utilization, use of stubbles, fodder conservation and supplementary feeding.]
It should be noted that in the earlier estimates (Carter 1974a), a total area of 3 million hectares of improved Medicago including marginal areas was considered with an assumed input of 50 kg N/ha. However, by retracting from some of the drier areas and using 2.5 million hectares of improved Medicago then the mean input should be c. 60 kg N/ha.

Although no detailed survey was made of the higher-rainfall areas in north eastern Algeria, two flights by aeroplane over and past this area plus two days of inspection at various points in this region together with appropriate maps indicated that there are approximately one million hectares of land potentially available for development of a very valuable livestock industry. Such development need not necessarily reduce the existing horticultural industries and should ensure that ample forest areas are left for commercial purposes, also adequate tree and bush cover retained for watershed protection on the steepest sites.

Throughout this higher-rainfall zone there is an abundance of native Medicago and Trifolium spp. together with annual and perennial grasses. There is no reason why a thriving dairy industry should not be developed in that part of the zone that is nearest Algiers e.g. in the Bordj-Menaiel, Dellys, Tizgirt-s-Mer and Tizi Ouzou areas. There are also opportunities for irrigation to supplement rain-fed pastures which could (and should) form the basis of any dairy industry in this zone.

Numerous areas were seen in this zone which either carried very poor crops or were virtually wasteland where it was obvious that there was a potential carrying capacity of 10 ewes/ha with minimum investment in pasture seed and phosphatic fertilizer. Hence there is a potential for an increased livestock population of c. 10 million ewe equivalents in this higher-rainfall north eastern zone of Algeria.

In summary, there is great potential for increasing livestock production in Algeria. This potential exists in both the traditional cereal-crop zone which has the potential to carry an extra 10 million ewe equivalents (provided that well-managed Medicago pastures are substituted for the fallow) and in the higher-rainfall hilly country where there is a potential to carry an extra 10 million ewe equivalents on semi-permanent legume-grass pastures.

However, it will not be easy to achieve these potential increases in livestock production. Firstly, pasture improvement must precede the increase in animal numbers; secondly, the insufficiency of good breeding animals will be a major constraint and thirdly, and most importantly, there will need to be many people trained in pasture agronomy, in pasture-livestock management and in crop-livestock integration.

* Depending on location, soil and drainage volunteer legumes include Trifolium fragiferum, T. repens, T. pratense, T. subterraneum and Medicago spp. and volunteer grasses include Lolium perenne, L. rigidum, Festuca spp., Dactylis glomerata and Phalaris tuberosa. In many areas all that is required is superphosphate application and proper grazing management.

Note: Ewe equivalents = Breeding ewes = 1.5 Dry sheep equivalents.
Increased cereal production in Algeria will occur through use of new high yielding varieties (HYV), improvement in seedbed preparation, more attention to depth and time of sowing and weed control. In the two years 1971 and 1972, HYV wheat production averaged 1400 kg/ha whereas durum wheat production averaged 620 kg/ha and soft wheat 830 kg/ha. With the increased production of HYV wheats there has been a concurrent increase in nitrogenous and phosphatic fertilizer usage. However, the postulated mean input of 60 kg N/ha by well-established Medicago in rotation with wheat should meet the nitrogen requirements under most cereal crop conditions. Furthermore, the grazing associated with the Medicago in the rotation will greatly reduce wild oats, ryegrass, phalaris, Oxalis pes-caprae and the cruciferous weeds.

It seems quite clear that, as new high yielding varieties of wheat are available with twice the yielding potential of older commercial varieties in Algeria, genotype is no longer a major constraint to production. From a modest area of 5000 ha in 1969-70 the area of high yielding wheat varieties expanded rapidly to 140,000 ha in 1970-71, 320,000 in 1971-72 and 600,000 ha in 1972-73 (CIMMYT Reports, Algeria, for 1971-72, 1972-73). If this trend continues, high yielding varieties will soon occupy the major wheat areas in Algeria and it is reasonable to predict a mean yield of c.1200 kg/ha in the near future i.e. a doubling of the 1961-72 yield (see Table 6).

In the 1972-73 season in Algeria there were approximately 750,000 ha of soft wheat, 1,550,000 of durum wheat, 840,000 ha barley and 60,000 ha of oats. The total wheat area is unlikely to expand so that on the above assumption of 1.2 tons/ha for a harvested area of 2.0-2.3 million hectares a wheat harvest of 2.4-2.8 million metric tons is a realistic goal. This would achieve national self-sufficiency at present and allow for stock-piling as a drought reserve for the human and livestock population as well as allowing some for export.

As with the livestock industry the attainment of the goal of doubling wheat production in the next few years will not be easy. It will involve a lot more precision in cultural practices and general farming operations than is common in Algeria at present. Even so the raising of wheat yields from 600 to 1200 kg/ha will probably seem simple by comparison to the task of lifting mean yields from 1200 kg/ha to say 1800 kg/ha on an area exceeding 2 million hectares in Algeria.

Just as wheat yields have been, and will continue to be, raised in Algeria so, too, will mean yields of barley and oats. These cereals will be of special significance as reserves for supplementary feeding of livestock on farms or for use in feed-lot enterprises.

In the quest for higher cereal production the multipurpose role of grazed Medicago pastures in rotation with cereals will be obvious. However, changed attitudes to stratification of the cereal and livestock industries will be essential in the interests of both cereal and livestock production. Proper integration of the cereal and livestock industries will only be achieved when there are livestock on the
traditional cereal farms throughout the year. This will ensure more and better-fed livestock and better weed control without reducing cereal production. With relevant investment in agricultural machinery, annual *Medicago* seed and superphosphate in addition to attention to genotype of both cereals and livestock (mainly sheep) cereal and livestock production should be complementary and both increase dramatically.

4. **Establishment and Management of Annual Medicago Pastures**

(a) **Local Ecotypes and Imported Cultivars of annual Medicago**

A detailed account of the annual *Medicago* species and varieties was provided by Heyn (1963) while Crawford (1970) has discussed natural variability in a collection of 206 lines of *Medicago truncatula* and Brock *et al* (1971) have described variability in *Medicago polymorpha* resulting from mutation. There is a considerable literature on the general distribution, role, and minor problems associated with the annual *Medicago* species (e.g. Trumble 1939; Andrew 1962; Amor 1965, 1966; Kleinig 1965; Quinlivan 1965, 1971; Robson 1969; Scott and Brownlee 1970; Barnard 1972).

There appears to be no shortage of well-adapted ecotypes of annual *Medicago* species in Algeria though there are no available seed supplies of these ecotypes. Despite the widespread occurrence of *Medicago polymorpha*, *M. truncatula*, *M. scutellata*, *M. ciliaris* and *M. orbicularis* these and other species are mostly confined to the unploughed roadways and are almost completely absent from the fields - this being ascribed to regular early and deep ploughing in preparation of the fallows for the subsequent cereal crop.

The stratification of native *Medicago* species in Algeria is, as expected, related to climatic (mainly rainfall) and edaphic (mainly soil texture, depth and water holding capacity) features of the environment. While there are no clear lines of demarcation the occurrence of species is approximately as follows.

*Medicago minima* is widespread on shallow soils and dry sites; *M. minima* and *M. laciniata* extend from the arid steppe regions with c. 100 mm rainfall up to about 350 mm rainfall. *Medicago truncatula* extends over the rainfall range, 150-450 mm; *Medicago littoralis* extends from about 225-500 mm mainly in the sandy coastal regions; *Medicago polymorpha* extends from about 350 mm upwards while *M. orbicularis*, *M. scutellata*, *M. ciliaris* and *M. intertexta* occur mainly on sites with mean rainfall exceeding 400 mm. Regarding the above species it was observed in Algeria that *Medicago truncatula*, *M. scutellata* and *M. orbicularis* favoured medium to heavy textured soils; *M. polymorpha* occurred on soils of light, medium and heavy texture; *M. minima* preferred medium to light textured soils while *M. ciliaris* occurred mainly on heavy textured soils. These observations are supported by those of Adem (1974) who in his studies of 68 ecotypes from 40 sites noted the apparent tolerance of *M. ciliaris* to semi-saline sites having high sodium levels and high cation exchange capacity. Adem also noted a range in pH of the 40 soils from 7.6 - 8.6 with a mean pH of 8.0. The rainfall and soil preferences of these Algerian species are reflected in the distribution of the naturalized annual *Medicago* species in southern Australia. The patterns of distribution are the same in both countries.

*According to Heyn (1963) these are *M. intertexta* var. *ciliaris* and var. *intertexta*. 
Relevant details of the five Australian cultivars of annual Medicago that were sown in Algeria during the 1972-73 and 1973-74 seasons are shown in Table 9.

**TABLE 9**

<table>
<thead>
<tr>
<th>Name</th>
<th>Weight/1000 seeds (g)</th>
<th>Seeds/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snail medic <em>(M. scutellata)</em></td>
<td>16.83</td>
<td>59,420</td>
</tr>
<tr>
<td>Paragosa gama medic <em>(M. rugosa)</em></td>
<td>6.00</td>
<td>166,700</td>
</tr>
<tr>
<td>Tornspecies disc medic <em>(M. tornata)</em></td>
<td>4.73</td>
<td>211,400</td>
</tr>
<tr>
<td>Jemalong barrel medic <em>(M. truncatula)</em></td>
<td>4.45</td>
<td>224,700</td>
</tr>
<tr>
<td>Harbinger strand medic <em>(M. littoralis)</em></td>
<td>3.06</td>
<td>326,800</td>
</tr>
</tbody>
</table>

* Commercial seed, not a registered cultivar as in the case of the other four species.

Further details of these commercial lines are given in the Register of Australian Herbage Plant Cultivars (Barnard 1972). All of these species are native to Algeria and it is worth noting that apparently excellent ecotypes of *Medicago truncatula* and *M. scutellata* from the high plateau in Algeria performed as well as, and better than, the Australian cultivars in preliminary row trials at El Harrach near Algiers during the 1973-74 growing season. As a result of these trials Adem (1974) reports that 20 promising ecotypes have been selected for further study as follows: *Medicago polymorpha* (5), *M. truncatula* (5), *M. scutellata* (3), *M. orbicularis* (4) and *M. ciliaris* (3).

The enormous variability both within and between annual species of *Medicago* ensures an ample range of adaptability to climatic, edaphic and biotic situations likely to be encountered in Algeria and elsewhere. There is very little evidence to support the need for a breeding programme. Crawford (1973) reported on his collection of 537 lines of annual *Medicago* from 53 countries and representing all 28 currently-recognized species and 51 sub-species. Certainly there is need to screen lines of *Medicago* on this scale before any breeding work can be justified. The cultivar Ghor *(M. truncatula)* is of current interest for South Australia and for Algeria as it will commence flowering 7-8 weeks from emergence about 4 weeks earlier than other early cultivars. Thus it is of interest in regions receiving < 300 mm rainfall. Crawford also refers to a line of *Medicago intertexta* var. *ciliaris* from a poorly-drained saline area of Israel, which flowers 25 days earlier than other accessions of this species i.e. it flowers as early as *M. truncatula* cv. Ghor. A line of *Medicago polymorpha* from Chile which flowers 4 days earlier than Ghor barrel medic is the earliest flowering genotype thus far recorded at the Parafield Plant Introduction Research Centre north of Adelaide. While no lines of *Medicago polymorpha* or *M. orbicularis* tested at Parafield had better seedling vigour than *M. truncatula* cv. Jemalong, all but 3 of the 43 lines of *Medicago intertexta* exhibited better seedling vigour and early herbage production than did Jemalong (Crawford 1973).
These few examples are cited merely to illustrate the great untapped potential of existing lines of annual Medicago. These must be assessed thoroughly before embarking on any breeding programme. Furthermore, in any evaluation of local ecotypes there must be adequate control plots representing a range of commercial cultivars to ensure that cost and effort is not expended on developing a "new" cultivar which may be already in commercial use under another name.

With regard to the experimental and field sowings of Australian cultivars of annual Medicago species in Algeria it was quite obvious that all five species could and would grow healthily at any of the sites including the high plateau. The best evidence for this was the satisfactory seed yield of all five species following an exceptionally late sowing in March 1973 at Mahdia and the regeneration and growth of these medic plots in 1974.

Critical evaluation of species is difficult under small drill-plot conditions because of firstly the confounding influence of seed size on emergence in relation to rough seed-bed conditions, lack of control of depth of sowing and late sowing, and secondly the lack of realistic grazing. There is no doubt that the relatively large seed of snail medic (Table 9) resulted in greater and/or more rapid emergence and early growth in several of the experimental sowings in Algeria. This is especially the case where emergence was difficult through deep sowing (there is a maximum potential elongation of the hypocotyl), heavy-textured wet soil, or mechanical impedance (e.g. soil crust). Thus Medicago scutellata looked impressive: however, because its large pods are easily prehended by sheep and goats, stands are often weakened through excessive loss of seed and consequent low density. It is clear that further experimentation using a wider range of both annual Medicago and Trifolium species is needed in the various environments of Algeria. On present indications Medicago rugosa and M. tornata appear less useful for the Algerian cereal zone than M. truncatula cv. Jemalong, M. scutellata and M. littoralis cv. Harbinger. For example Medicago ternata cv. Tornafiel was severely frosted at Beni Slimane in April 1974 and M. rugosa cv. Paragosa appeared pale and not properly nodulated in several experiments. However, both of these apparent failings may have been very different with earlier sowing dates, although it is known that Medicago rugosa has more specific rhizobial requirements than M. truncatula and M. littoralis and that M. tornata prefers neutral or slightly acidic sandy soils (Barnard 1972).

In summary, choice of species or cultivars for sowing in Algeria should be influenced by the native Medicago flora of the roadsides. In all areas, including the severe environment of the Setif district, excellent healthy self-sown Medicago polymorpha and M. truncatula occur on the roadsides. Therefore, the imported cultivars (e.g. Jemalong, Hannaford, Cyprus and Ghor) of Medicago truncatula and locally-collected Medicago seed (predominantly M. polymorpha) at present have a widespread place in the cereal belt. It is worth noting that local mixed Medicago seed collected in Oran produced weak plants that appeared poorly nodulated at Telagh but produced satisfactory to excellent medic stands at Beni Slimane and other sites. In brief, much more experimentation is needed to sort out all the details: however, large scale sowings can still proceed with a reasonable chance of success providing
that there is more attention to seedbed preparation, methods of sowing and grazing management.

(b) Seedbed Preparation: Rate, Depth and Time of Sowing

The typical rough seedbed that is commonly used for cereals in Algeria is quite unsatisfactory for annual Medicago species for three main reasons - there is no proper control of depth of sowing, there is excessive soil aeration in dry periods and there is inadequate seed-soil contact (see Carter and Saunders 1970).

In the 1973-74 medic-sowing campaign in Algeria, although there were some fair stands of annual medic resulting from better seedbed preparation and control of depth of sowing (e.g. at Oran, Oued Tiolat, Sfisef, Sidi-Bel-Abbes, Mahdia, Beni Slimane, El Khemis, Constantine and Guelma) the percentage establishment* of the various Australian cultivars of annual medic in both experimental and field-scale sowings was generally very poor. Furthermore, because of many instances of late sowing these medics were generally less advanced than the self-sown species. In several cases *Medicago scutellata* (and, to a lesser extent, *M. rugosa*) showed best establishment, apparently due to the larger seeds.

The most disappointing field seen was a very roughly-prepared 20 hectares on Domain Hassaine Mohamed at Setif sown to Jemalong barrel medic on November 16, 1973 and showing a zero establishment when inspected on April 4, 1974. The fact that there were very healthy *Medicago truncatula* and *M. polymorpha* plants on adjacent unploughed areas indicated that there was no species problem: it appeared to be simply a dramatic example of the effects of poor seedbed preparation and sowing technique.

Having regard to the generally poor establishment especially of field-scale sowings of *Medicago* apparently resulting from sowing too late and/or too deep (due to lack of suitable machinery and lack of experience) these problems being further aggravated by medium to heavy soil texture and rough seedbed preparation, it is recommended that annual *Medicago* species be dry-sown in autumn during September-October with 25-50 kg P₂O₅/ha (depending on phosphate history) and without nitrogenous fertilizer (because these nitrogenous fertilizers encourage the non-legume species that compete with the *Medicago* seedlings).

In this program of autumn dry-sowing it is important to ensure adequate seed-soil contact by shallow seed burial. Shallow scarification of the dry soil surface to a depth of 1-3 cm, dropping the medic seed and superphosphate onto the surface and covering with trailer harrows, boughs of trees or bushes is a satisfactory and cheap method of sowing. The Australian type combine (combined scarifier and drill) as shown in Plate 5 or the more-recent, large-capacity, sowing implements such as the Shearer Wideseeder are ideal implements for dry-sowing into stubble or bare ground as the tynes scarify the soil surface and provide sufficient loose soil

* This refers to the number of healthy seedlings per unit area in relation to the number of viable seed sown, expressed as a percentage.
to cover the medic seed that is dropped. Where machinery is available with separate small seed boxes, or facilities for sowing small seeds through the cereal grain box these should be used. Alternatively the seed and phosphatic fertilizer can be mixed together for sowing but it should be mixed for the shortest time that is practicable. The covering procedure will ensure that seed and fertilizer are not concentrated in too narrow a band leading to possible depressed germination in slightly damp soils. Various disc implements, for example trash multisowers, disc drills and disc sod-seed drills may also be used for the dry-sowing programme providing either that these implements can penetrate sufficiently to allow soil movement for coverage of the seed or that they are used following a conventional scarifier or heavy-duty cultivator or disc cultivator. Whatever method is used it is essential to loosen the surface soil to ensure seed coverage. An average sowing depth of 0.5-1 cm is ideal.

It should be emphasized that commercial *Medicago* seed is scarified during the threshing and cleaning processes and has a much lower level of hardseededness hence higher current germination capacity than does medic seed in the field*. Therefore, it is possible to get a high percentage emergence of sown commercial medic seed following a good rain in autumn and to lose a high proportion of these seedlings in a following dry period (i.e. a "false break" to the season). Thus there is a great deal of merit in sowing 5 kg/ha rather than 10 kg/ha of seed in the proposed dry-sowing programme. At best, a good stand of medic on an area twice the size will result from the 5 kg/ha sowing. At worst, the procedure can be repeated in the next stubble year, two years later. In other words, there is great merit in spreading the risk over a number of years.

Where land has been carefully prepared and levelled for seed production and harvesting then it is wise to retain the general 10 kg/ha sowing rate. Likewise, those sowings made after a definite break to the season should retain the 10 kg/ha rate of sowing if there is no significant medic component in the volunteer pasture. However, where there is a significant component of useful *Medicago* species two options are available as follows;

1. delay sowing *Medicago* until the next stubble year and hope that there will be sufficient reserves of medic seed, by that time, or
2. use a disc drill, or preferably a disc sod-seed drill, to sow more (say 5 kg/ha) medic seed with minimum soil disturbance. A small length (20-30 cm) of chain dragged immediately behind the sowing discs will ensure adequate seed coverage which should not exceed 1 cm of damp soil - especially on heavy-textured soils.

(c) Management of Annual *Medicago* Pastures

Regarding the management of annual medic there must be a compromise between pasture production and utilization, weed control and medic seed production. Until a very good stand is established with perhaps 300-400 kg/ha of seed of various

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* Crawford (1970) reported that of 206 lines of *Medicago truncatula*, 99 lines had 100% hardseededness at maturity and only 6 had more than 2.5% permeable seeds. At the end of March (= September Algeria) only 14 lines had a higher percentage of permeable seed than did cv. Jemalong (with 9%).
ages, grazing or mowing should not be below a height of 8-10 cm during the growing period. To ensure maximum seedset, grazing of new medic stands during flowering and pod formation should be reduced as far as practicable. However, if the medic is suffering from severe competition for light or moisture by taller-growing species then there must be a compromise and the medic mown (or grazed if sufficient animals are available to rapidly remove the unwanted species) at a height not less than 10 cm. During the dry-pod stage grazing must again be a compromise between reasonable utilization of dry feed and ensuring an adequate carry-over of hard seed (which will persist in the cultivated soil under the following cereal crop). Heavy grazing of dry herbage residues will reduce the quantity of carry-over seed. On the other hand, it is inadvisable to leave a dense dry cover where the medic stand is being allowed to stay for a second year (especially in the case of seed production) as this dry herbage will form a "blanket" and severely depress the emergence of seedlings. The use of a disc implement to break-up the dry cover can help in these circumstances: however, the common suction-harvesting process normally removes adequate herbage with the seed to prevent these problems.

The actual loss of mature Medicago seed by grazing depends on many variables e.g. the species of medic (determining average seed size and degree of hardseededness) and the period of summer or autumn (determining the intake and digestibility of herbage consumed with the pods as well as the degree of break-down of hardseededness). Large smooth pods with large seeds are affected most e.g. Medicago scutellata because sheep and goats can easily prehend the pods. Thus the large seed is partly crushed by the molar teeth and there are losses of seed during passage through the digestive tract and losses of viability of seed voided with the faeces. The smaller the seed, the rounder the seed, the higher the percentage of hard seed and the higher the average digestibility of feed (leading to more rapid passage through the animal) the less the loss of viable Medicago seed.

There have been too few detailed studies on the intake of pods by ruminant livestock and the fate of these ingested pods. Vercoe and Pearce (1960) reported mean daily intakes of 940 g of pods of Medicago truncatula in a digestibility trial. This intake included 260 g of seed (268,000 seeds/kg, 98.2% of hard-seed, 45.2% crude protein) of which the average seed number defaecated ranged from 120 to 3160/day (0.12%-3.13% of actual seed ingested by the sheep in the trial). However, Smith (1963), in digestibility studies involving the feeding of commercial seed samples (i.e. seed with relatively low percentages of hard seed) in rations comprising 40% seed and 60% chaff, found 8% of the ingested seed of Medicago truncatula was voided as whole seed. Clearly neither of these studies can supply all the answers to the field situation where there is ample evidence that medic pods are eaten by livestock and, depending on the relevance of the variables previously mentioned also the class of livestock, differing quantities of viable seed are voided and hence dispersed by the grazing animal.

It should be appreciated that during the phase of pasture development, grazing of medic must be much more carefully controlled than at a later stage when there are large amounts of hard seed of Medicago in the soil in addition to the potential seed
yield of the current crop of medic. Correct grazing and cutting management is as much an art as a science. On well-established medic pastures there is no reason why a hay-cut should not be taken providing mowing height be not less than c. 8 cm to ensure adequate seed-set and carry-over seed.

Apart from phosphorus deficiency symptoms of medic on some areas, mainly on poorer soils in the Private Sector, there was no indication of other fertilizer requirements for annual medic pastures in Algeria. Therefore, until such time as there is unequivocal experimental evidence confirming other deficiencies superphosphate at 25-50 kg P₂O₅/ha should suffice during the medic establishment phase. Further experimentation will be needed to determine optimum levels of application of phosphatic fertilizer to the annual medic pastures in relation to climatic and edaphic factors as well as the rates of phosphatic fertilizer being used with the cereal crops in the rotation. Where 45 kg P₂O₅/ha are used with the cereal crop there should be some residual phosphorus for Medicago on many soils.

While there were no obvious signs of plant pathogens at the time of the Algerian survey (March-April 1974) there is always a possibility of fungal attack depressing emergence or causing losses through "damping-off" of seedlings under the cold, wet conditions following emergence (Kleinig 1965). Likewise there were few signs of insect pests. The only damage noted was by lucerne flea (Smyntthurus viridis) on both volunteer and introduced Australian cultivars of medic at Oran in April 1974. However, this damage was not serious.

(d) Production and Harvesting of Medicago Seed

Although there is no shortage of annual Medicago ecotypes in Algeria there is a shortage of seed. In the short-term seed can be imported from southern Australia but in the longer-term Algeria should aim to become self-sufficient in medic seed. However, it will be difficult, if not impracticable, to produce pure seed of the various cultivars of Medicago because of the widespread occurrence of volunteer Medicago in Algeria. But such impurities are no real practical disadvantage: the objective in Algeria is to increase the density of medic pastures and the reserves of hard seed as quickly as possible by using both local and imported seed. Impurities of medic are no problem except in pure seed production of medicas.

Extensive site preparation involving shallow tillage and levelling of fields will be essential for the efficient operation of any suction harvester on those areas with sufficient Medicago to warrant harvesting. The Horwood Bagshaw suction harvester (Plate 1) is still the best machine commercially available but it is relatively slow (c. 0.5 ha/hour) and these machines normally are capable of harvesting only about 200 ha per season. Some farmer-modifications to this harvester and farmer-constructed machines are superior in terms of area covered and quality of seed sample. These improved machines involve pre-cleaning of the gathered pod material before it goes into the thresher. Rolling of seed crops during the vegetative stage when the soil is damp can assist the harvesting process by pressing in stones and breaking soil clods.
Medic stands benefit from grazing but until the stand is very well established grazing should not be below 8 cm and grazing should cease at the commencement of flowering. As stated previously, there must be a compromise between medic feed production and utilization, seed yield and weed control by cutting and/or grazing. Yields in the range 200-600 kg/ha of clean seed are quite realistic under good management. It is considered that c.A$65/ha is an average cost of production and assuming a price of 55 c/kg for clean seed this means that 118 kg/ha of seed marketed is needed for a break-even yield. In round figures, a 200 kg/ha medic seed yield can be expected to give the same gross margin as a 2000 kg/ha wheat crop in the South Australian cereal belt (Ragless 1973).

With regard to the practical problem of securing stocks of seed of the annual Medicago species, it was mentioned previously (page 31) that 2.5 million hectares annually in Algeria might be growing improved medic pasture in a two-course rotation with cereals. Thus there are 5 million hectares to be improved with annual Medicago and superphosphate in the cereal zone of Algeria. Assuming that an area of 1 million hectares has sufficient volunteer Medicago and that an average of 7.5 kg/ha is sown on the remaining 4 million hectares this requires 30,000 metric tons of Medicago seed.

If this seed were grown in Algeria it would require 10,000 ha of annual Medicago seed crop averaging 300 kg/ha in each of the next ten years. The alternative is to import a substantial part of this seed requirement from southern Australia. It seems reasonable to compromise and to import certified seed for sowing in selected areas of Algeria with the idea of harvesting these areas for seed. However, without considerable expertise in sowing and maintaining the medic stand, also in harvesting and processing the seed, the cost/kg of Algerian-grown seed is not necessarily going to be any less than the cost of importing Australian certified medic seed. Seed price must be based on trueness-to-type, purity, germination and freedom from undesirable weeds.

Having regard to the gross deficit of medic seed in Algeria it is important that every effort be made to harvest as much seed as practicable but taking care to ensure that harvested areas are not depleted of pods. The sheep-skin roller, the rotary broom and hand rakes and brooms are all useful alternatives to the Horwood Bagshaw suction harvester. However, the sheep-skin roller can only collect pods that have some degree of spine development.

Finally, it is important for Algerian technicians to study at firsthand and get actual practical experience in all phases of medic seed production in South Australia. Likewise Australian technicians could assist in medic seed production in Algeria.
V. RESEARCH PRIORITIES FOR PASTURE-LIVESTOCK PRODUCTION IN ALGERIA

1. General Considerations

In previous sections of this report mention has been made of the fact that it is unrealistic to segregate cereal production and livestock production enterprises in Algeria and that there is a great need for cereal-livestock integration. However, in view of the excellent progress being made by the cooperative Cereals Project in raising cereal production in Algeria, no direct reference will be made here to research on cereal production, although there are some obvious areas of common concern (e.g. tillage practice, time of sowing in relation to establishment, optimum fertilizer use). Thus the emphasis in this section will be on research priorities directly related to pasture and forage production and consequent livestock production.

In Algeria there is a clear need for new farming systems involving the integration of crop and livestock enterprises. There is need to demonstrate that sheep can be kept all-year-round on cereal farms. Problem-orientated research is needed to assess the biological and ecological possibility and potential for increased livestock production while concurrent research studies are required to show the social and economic practicability of new systems of production. Integrated research studies must be amenable to both statistical and economic analysis. Technological research is wasted if the results cannot be applied, or adapted, or are unacceptable because of cultural, social or economic constraints.

For an effective programme of research on pasture and livestock production to meet the increasing demands of the human population in Algeria, multi-disciplinary research involving specialists in soil fertility, soil water, pasture and crop agronomy, rangeland ecology, livestock production (feeding, selection and breeding) and socio-economics is required. In this respect it is essential to ensure fully-coordinated agricultural research in Algeria. It would appear that more liaison and coordination of efforts is needed between the various Algerian national groups, and between national and international groups to ensure maximum benefit from both Algerian and overseas research. Staff and students at the Universities (especially INA, El Harrach and ITA, Mostaganem) should be involved more in helping to ensure continuity of research effort along important lines of agricultural research. Many relatively simple, but important, agricultural problems could well be tackled and answered for differing environments and in sequential years by a series of Ing. Agron. theses (see V,3.).

Special funds to encourage relevant, high-quality agricultural research by the Universities would assist teaching and also the research outlook of Algerian students. It would be a sound investment in Algeria.

The production of meat, milk, wool and mohair from grazing ruminant livestock is a function of yield, percentage utilization and the within-animal efficiency of conversion of pasture or forage. In Algeria, as in other countries of the Near East and North Africa, the outstanding constraints to increasing production/head, and production/unit area/unit time, are the generally low yields of pastures and
forage crops, and relatively poor quality of much of the feed. Shortage of grazed pasture or forage is frequently aggravated by deficiency of dietary energy in winter and dietary protein and energy in summer. Also there is the over-riding problem of lack of reliability and continuity of supply of pasture or forage, or stubble grazing, or conserved supplementary feed. However, the obvious way of improving the feed supply (both quantity and quality) is by the introduction of leguminous pastures and forage crops, especially annual Medicago species, into the crop rotation in the rainfed cereal zone and irrigated crop zones and by pasture improvement in the higher-rainfall areas. This improved crop-livestock integration will involve a substantial reduction in the fallow, an improvement in cereal yields, and at the same time provide a more stable and improved farm income.

A major factor relating to the efficiency of conversion of feed within the animal concerns the age at time of marketing: a high priority in research is to examine systems that ensure that animals reach an adequate bodyweight at a younger age. This will involve not only better feed supply but also attention to general livestock husbandry practices, animal health, and, in the long run, selection within existing native breeds and cross-breeding with exotic breeds. This links with the studies on pasture and forage crop productivity insofar as nutritive value, particularly digestibility, and the general and specific role of fodder conservation and supplementary feeding are concerned. For example, the supplemental feeding of underfinished lambs to ensure earlier offtake from the Algerian steppe has biological, economic and ecological implications. Though feed may be relatively expensive, the cost of this supplementation has to be assessed against the alternative of having to retain the lambs for a longer period thus aggravating the worsening condition of the steppe.

2. Research Programmes and Priorities

For Algeria as a whole, the five broad research programmes listed in order of priority below are the most urgent ones related to increasing production from ruminant livestock. All involve multi-disciplinary studies and are to a considerable extent interlinked.

The first three research programmes embracing the ecology, production, management and utilization of sown pastures and forage crops, together with the role of fodder conservation and supplementary feeding (including feed lots) involve the joint problems of increasing soil fertility for the cereal crop and increasing feed supply for ruminant livestock. As the plant introduction and testing programme will need to be orientated mainly towards pasture and forage legumes (particularly within the genera Medicago and Trifolium) this will involve cooperative studies on tillage practice, fertilizer use, reduction of the fallow area and on the general integration of crop and livestock production enterprises. These studies should be concentrated mainly in rainfed agricultural areas with mean annual rainfall not less than 350 mm.

The fourth research programme on rangeland ecology and management is envisaged as part of the overall plan of multi-disciplinary studies to facilitate inter-zonal
movement of livestock to alternative fattening areas, or feed lots, with the aim of reducing grazing pressure on the steppe and concurrently to seek ways and means, by research on management procedures, to arrest further decline in the productivity of the Algerian rangelands. The revegetation of denuded steppe seems economically impracticable unless it is for a very specific purpose when well-known pitting and furrowing techniques to catch seed and water may be feasible. On steep hill and mountain pastures there is justification for revegetation where there is a problem of protecting watershed areas and this may need some research related to applying well-accepted principles of soil conservation (see Section II,1.).

The fifth research programme concerning the improvement in potential productivity per head of ruminant livestock, though of importance, must be subsidiary to the main problem of ensuring more and better feed on a continuing basis. However, because of the long-term nature of animal selection and breeding programmes it is desirable that these studies should proceed as soon as practicable after the research programmes on pastures and forage crops are initiated in Algeria.

(a) The Ecology and Production of Pasture and Forage Species

Of high priority is the further evaluation, by botanical survey in spring, of existing native and natural pastures in the cereal-crop zone and higher-rainfall areas of Algeria to assess botanical composition, plant density and yield hence the likely role of fertilizers to encourage pasture growth, especially annual legumes, for increasing soil fertility and livestock feed supply and for protecting the soils from erosion. These surveys should be followed by fertilizer experiments (with emphasis on rates of superphosphate), with and without the sowing of additional seed, in the following autumn to assess potential dry matter yields in various agro-climatic zones of Algeria. These studies should include spring core-sampling for hard-seed reserves of Medicago spp. and Trifolium spp. and summer sampling for total seed mass to predict the need for further seed on each surveyed area.

A major research programme should involve the collection and evaluation under various fertilizer and grazing management systems of both indigenous and introduced pasture and forage legumes especially annual Medicago and Trifolium species. A lesser programme should involve salt-tolerant pasture species needed for permanent cover on salt-affected areas. Methods of establishment, and the yield potential, persistence, seed production and self-regeneration of these species require study. As light competition, and/or moisture stress, will determine potential dry matter production in most situations (i.e. total yield of dry matter will be correlated with density) the main emphasis should be on ease of establishment, seed production, re-establishment and persistence of the annual legume species. Fertilizer and plant protection requirements will also need assessment. [This research programme is linked to (b)].

* Including re-introduction of species originally from the Mediterranean Basin.
With regard to the programme of plant introduction and testing it is strongly recommended that species and cultivars be tested widely as early as practicable in small hand-sown, randomised block, sward trials. Plots of 2 m x 5 m will suffice. Two replicates of the following six cultivars of barrel medic (Hannaford, Jemalong, Cyprus, Cyfield, Borung, Ghor) together with Harbinger, Paragosa, Tornafield, Murrayland and Snail medic as well as Clare subterranean clover, together with the best of the local Algerian ecotypes, should be sown on well-prepared stubble land in a widespread testing programme in the cereal zone of Algeria. Seed should be sown on the basis of 10 kg/ha of pure germinating seed, with a basal fertilizer application of 50 kg P₂O₅/ha and plot areas should be fenced to exclude grazing. The combined data from such trials would give a clear picture of the adaptability, potential winter yield, total yield and seed production. One half of each plot should be mown at not less than 8 cm in height at the fully-green, early seed-setting stage (after sampling for total yield), to examine the effect of mowing and herbage removal on seed-set, seed-dormancy and hardseededness during summer and autumn.

The trends in seed dormancy and hardseededness, which are so important for persistence through the cropping phase, should be studied through summer and autumn prior to removal of fencing and ploughing for the crop. The re-establishment of the various species and cultivars, though plot boundaries will be somewhat obscured, should be assessed in the following stubble year.

Experiments on seedbed preparation also rate, depth and time of sowing of pasture in both the cereal zone and higher-rainfall areas of Algeria are required. While the main emphasis should be on production and persistence of Medicago in the cereal belt there is scope for sowing mixed Medicago-Trifolium pastures in the higher-rainfall areas of Algeria.

(b) The Management and Utilization of Pasture and Forage Species

At present, in the early stages of experimentation on ways and means of substituting grazed annual legumes for the fallow, and especially before a final choice is made of the best introduced cultivar (or cultivars) or local Algerian ecotype (or ecotypes) to use in a particular locality, there is no merit in attempting detailed grazing experiments as these are too expensive in terms of time and inputs of resources. However, there is merit in determining yield of the pasture under grazing where total yield of dry matter is expected to exceed 9000 kg/ha. This is relatively simply done by the "open" and "closed" quadrat method of McIntyre (1946) described by Carter and Day (1970). Where total dry matter production of medic or clover (plus grass and weeds) does not exceed c. 9000 kg DM/ha then a single end-of-season harvest for dry matter determination will adequately predict total yield. Where yields are higher, more harvests are essential (Carter 1974b).

In the longer-term, research is needed on the soil-plant-animal interrelationships of stocking rate, grazing method and type of livestock on both sown pastures and forage crops; also on the manipulation of potential annual dry matter production by use of special-purpose pastures and forages, by fertilizers, by supplementary
watering, etc.; and the utilization of the pasture or forage by in situ grazing, zero-grazing (cut and cart) and other methods. [This research programme is linked to (a) and (c)].

(c) Fodder Conservation and Supplementary Feeding

The biological and economic advantages of conservation and feeding of pasture and forage crops, also grain and crop residues, needs careful assessment in Algeria. The comparative advantages of feedlot finishing of sheep and cattle using green forage or dry fodder versus in situ grazing on green pasture needs careful study. This research will involve the compounding of feed rations from local feedstuffs. [This research programme is linked to (b) and (d)].

(d) Rangeland Ecology and Management

The seed-seedling dynamics of both annual and perennial plant species and the methods for soil protection and erosion control need detailed study in relation to nomadic and transhumant grazing in the arid steppe, and unimproved highland and mountain pastures. The important need to reduce grazing pressure is closely linked to the provision of alternative outlets for young and older animals. This ready transfer (e.g. by road transport) to fattening areas or feedlot facilities would require new attitudes to cereal crop-livestock integration and involve the whole socio-economic complex. [This research programme is linked to (b) and (c)].

(e) Sheep, Goat and Cattle Selection, Breeding and Management

While the greatest constraint to increased sheep, goat and cattle production is the deficit in feed quantity and quality, there is scope for improvement by selection within existing breeds. With the anticipated provision of sown pasture and forage crops in the cereal zone, the higher-rainfall areas and, to a lesser extent, in the irrigated zone hopefully there will arise a settled livestock industry in many areas. This will require a more productive animal to better utilize the improved nutritional environment. Hence there will be scope for cross-breeding with exotic breeds. The potential quantity and quality of meat, milk, wool and mohair production will need evaluation for the various selections and cross-bred flocks and herds.

With increased feed supplies, better animal offtake at a younger age will be possible but will require improved management which in turn will require research, for example on the minimum and optimum age of weaning for sale or transfer of rangebred lambs to fattening area or feedlot. [This research programme is linked to (b), (c) and (d)].

3. Suggested Research Projects of Practical Importance in Algeria

In the previous pages of this report it has been emphasized that the introduction of Medicago cultivars, or the encouragement of existing ecotypes of Medicago in the cereal zone, and pasture improvement based on both Medicago and Trifolium in
the higher-rainfall areas hold the key to:

1. increased production of both cereals and livestock,
2. the potential for better cereal-livestock integration and
3. better preservation of soil and rangeland resources in Algeria.

Therefore, it is a matter of top priority to develop an accelerated rate of research on the ecology, production, management and utilization of pastures and forage crops to complement the work on cereals undertaken by the Cereals Project in Algeria.

A few research projects of direct relevance and of practical importance in Algeria are suggested below. Many of these could be undertaken for thesis requirements by Ing. Agron. undergraduate students. Furthermore, as several of these projects need to be replicated in time and space, this also caters for thesis requirements.

(a) Levy Point Quadrat Surveys

These should be made during spring in both the cereal zone and higher-rainfall areas to assess the status of native and natural (volunteer) pastures with special emphasis on *Medicago* and *Trifolium* in relation to past cultivation treatment and phosphatic fertilizer history (refer III.5. Table 7). Point data on density (veg. hits/100 points) and botanical composition should be correlated with actual yield and botanical composition of pasture samples harvested to ground level. Core-samples (c. 10 cm diameter) should be taken to determine hard-seed reserves of *Medicago* and *Trifolium* in the soil which should be related to current density in the pasture.

(b) Ecological Studies on Regional Ecotypes of Annual *Medicago*

The autecological studies (initiated at INA, El Harrach, by Professor Conesa and his assistants) should continue using the existing promising lines, and further comparative ecological and production studies using Australian cultivars as standards are required. Winter production of herbage, total dry matter production and total production of viable seed are most important.

(c) The Effect of Superphosphate on Productivity of Leguminous Pasture

Experiments are required in Algeria on both native (undisturbed sites), volunteer and sown pastures of *Medicago* and *Trifolium* to assess the impact of various rates and forms of phosphatic fertilizer on yield and botanical composition, seed production and regeneration (especially *Trifolium* spp.). Rates of 0, 25, 50 and 100 kg P₂O₅/ha/annum should suffice in preliminary studies. More elaborate combinations of rate and frequency (e.g. Carter 1970) can be used in more detailed experiments at a later stage.
(d) The Effect of Seedbed Preparation, Time and Rate of Sowing Pasture Legumes

Experiments are needed in the cereal zone and higher-rainfall areas of Algeria involving factorial combinations of the following treatments after shallow dry scarification of the soil:

<table>
<thead>
<tr>
<th>Sowing Methods (2)</th>
<th>x</th>
<th>Sowing Rates (3)</th>
<th>x</th>
<th>Blocks (4)</th>
<th>= 24 plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early (dry) sown</td>
<td></td>
<td>5 kg/ha seed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Later (wet) sown</td>
<td></td>
<td>10 kg/ha seed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 kg/ha seed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The importance of such studies using annual Medicago species on the alkaline soils of the cereal zone and a mixture of Medicago and Trifolium in longer-term pastures on the more-neutral to acidic soils of the higher-rainfall areas relates to the potential savings in cost of seedbed preparation, the advantages of early sowing and the advantages of heavier sowing rates for early winter production and for controlling weeds. The main data collection should relate to legume emergence and establishment, winter yield and total yield, botanical composition (sown legumes, volunteer legumes, grasses, other species) and seed production.

(e) The Effect of Cover Crops on Establishment of Pasture Legumes

In Algeria, the extensive spraying of cereal crops with herbicides for weed control precludes the general undersowing of pasture legumes. However, in some areas of Algeria, undersowing may be an economic proposition although the prospects are not good where nitrogenous fertilizers are used to promote cereal production. It should be mentioned that cover crops generally become "smother" crops in similar dry environments of southern Australia; but cover crops are used in some areas (see Carter and Heard 1962). Simple experiments are needed in the various cereal-cropping and higher-rainfall pasture areas of Algeria involving wet-sowing, with basal superphosphate, of 5, 10 and 20 kg/ha of legume seed with and without say 10, 20 and 40 kg/ha of cereal (wheat, oats, barley or triticale). The legume seed must be surface sown (preferably from a separate seedbox) and covered with light trailing harrows. Obviously the same tyned or disc drill must be used for all plots to prevent bias in the degree of compaction and tillage. Data needs to be collected on yield of pasture + forage crop through the season together with the more critical data on legume establishment, survival and production of viable seed.

(f) The Effects of Plant Density on Productivity of Pasture Legumes

Experiments on the effects of sowing rate on the productivity of both medics and clovers are needed in Algeria. Small, hand-sown plots (say 4 x 2.5 m) on well-prepared soil in a randomized block design using commercial annual legume seed of known purity and germination capacity can provide valuable information especially on the impact of plant density on yield of pasture in winter. As total
medic seed yields of 500-600 kg/ha are quite feasible the design might be as follows:

\[
\text{Sowing Rate (8)} \times \text{Blocks (4)} = 32 \text{ plots}
\]

5, 10, 20, 40, 80, 160, 320, 640 kg/ha of commercial seed

As total seed yield of Trifolium species is often much higher than the rates shown above, then an additional rate of 1280 kg/ha is warranted. Data should be collected on emergence, yield and density at 4-weekly intervals through the growing season, botanical composition, pod yield and viable seed yield.

(g) The Effects of Seed Size and Sowing Depth on Emergence of Pasture Legumes

The potential genotype by sowing-depth interaction with regard to establishment of annual Medicago species under rough seedbed conditions has been mentioned earlier in this report. In particular, Medicago scutellata, because of its large seed, emerged and grew more rapidly than other species. In Algeria, plant emergence problems are aggravated by the poorly-structured, heavy-textured soils. Experiments are needed with treatments comprising:

(1) **Different species with differing mean seed sizes**, sown at equivalent rates of pure-grown super seed e.g. 20 kg/ha p.g.s.

(2) **Same species with differing seed sizes** (obtained by sieving, i.e. within species variation in seed size, and rate of sowing adjusted for germination capacity of sieved seed)

(3) **Different species with the same seed size** (obtained by sieving, and rate of sowing adjusted for germination capacity of sieved seed)

Depths of sowing of 0.5, 1.0, 2.0, and 4.0 cm into sand, loam and clay are suggested. For adequate control of experimental detail these experiments should be done in pots or boxes. Watering treatments could be imposed. The most important data relate to rate of emergence, total percentage emergence and dry matter yield say 4 weeks after sowing.

(h) The Digestibility of Medic Pods and Seeds

Studies are required on the very practical problem of losses of Medicago seed following ingestion of pods by sheep and also the loss of viability of the apparently-normal seeds that are voided in the faeces

(1) **Supplementary Feeding of Store Lambs**

Experiments are needed to assess the relative intake, selectivity, and body weight gain of store lambs fed various coarse-grain supplements at levels of 0, 250, and 500 g/day mixed with a basal level of cereal chaff (say 500 g/day).
VI. CONCLUSIONS AND RECOMMENDATIONS

(1) There is great potential for increasing both the cereal crop and livestock production in the cereal zone of Algeria through large-scale replacement of the fallow by productive self-regenerating annual *Medicago* species. It is realistic to envisage the improvement of 5.0 million hectares (by sowing medic, encouraging existing volunteer medic, and using superphosphate) of which half is cropped and half is grazed each year in a cereal-medic rotation. If properly managed, these grazed *Medicago* pastures should provide:

- A soil nitrogen increment of 60 kg N/ha worth US $45 million per year.
- Increased levels of soil organic matter, improved soil structure and infiltration.
- Control of weeds through competition with *Medicago* and through livestock grazing.
- Improved cereal yields. A mean wheat yield of 1200 kg/ha and a harvest of 2.5 million metric tons of wheat is a realistic short-term goal.
- An increase of 10 million metric tons (DM) of high quality green pasture, hay and dry feed which could feed an extra 10 million ewe equivalents per year and still leave ample soil cover and medic seed.

(2) To achieve these potential increases in production in the cereal zone of Algeria there will need to be substantial financial investment in:

- Well-designed and strongly-constructed agricultural machinery incorporating the SJ principle, and of the trailing type with large wheels, to allow rapid shallow tillage and sowing operations and to level the seedbed.
- Additional soluble phosphatic fertilizer especially in the private sector.
- Annual *Medicago* seed: c. 30,000 metric tons are needed.
- Training at all levels of cereal and livestock production: e.g. farm machinery operators, farm managers, and research and extension personnel concerned with cereal and pasture agronomy, pasture-livestock management and the integration of cereal crop and livestock enterprises.

However, these investment costs should be quickly recouped through nitrogen fixation by the *Medicago* pastures, reduced costs of tillage and weed control, decreased soil erosion, increased cereal yields and increased yields of livestock products.

(3) Pasture improvement in the cereal zone of Algeria will provide scope for cereal-livestock integration within this zone and the opportunity for close integration of cereal-crop and livestock enterprises between the cereal zone and the adjacent steppe zone. This will allow reduction of grazing pressure on the steppe by providing for organized offtake from the steppe to fattening areas or feedlot units in the cereal zone.

(4) There is great potential for increasing livestock production in the higher-rainfall zone of Algeria through use of long-term improved pastures based on both *Medicago* and *Trifolium* species and associated annual and perennial grasses with adequate superphosphate. There is a realistic potential for an increase of 10 million ewe equivalents in this higher-rainfall zone which is ideally suited as a livestock breeding and fattening area and the logical area for expansion of the dairy industry.
At present the total livestock (sheep, goats, cattle, donkeys, mules, camels and horses) in Algeria approximates 20 million dry sheep equivalents. Thus the potential increase of 20 million ewe equivalents in the cereal zone plus higher-rainfall zone would involve an increase of 150% in total livestock units. However, having regard to the general lack of experience in intensive pasture and livestock management, it is reasonable to aim first to increase livestock by 5 million ewe equivalents in both the cereal zone and the higher-rainfall zone which would represent a 75% increase in livestock units. It is possible to achieve this goal within ten years.

The development of the poultry industry in Algeria, though in part dependent on increased grain production, should assist the development of the sheep, dairy and beef industries by helping to minimize slaughter of these ruminant livestock. Ducks and geese could greatly assist in weed and pest control in the citrus groves, orchards and vineyards.

Because of the long-term nature of investment in pasture improvement and development of flocks and herds in Algeria, adequate production incentive must be provided through Government policy on agricultural credit, on prices of cereal and livestock products and on security of land tenure.

While there are many urgent measures that can be taken to ensure success of the Medicago-cereal rotation in Algeria (e.g. by reducing depth of tillage to a maximum of 8-10 cm, dry-sowing of annual Medicago and using more superphosphate), there is need for an accelerated research programme on the ecology, production, management and utilization of leguminous pastures and forage crops and on consequent livestock production to complement the research programme on cereal production.

There is need to ensure that agricultural graduates and diplomates receive a broader-based training more suited to tackling the problems of Algerian agriculture. Candidates for higher degrees should be sent to get relevant overseas training related to production research.

Finally, to guarantee that food crops and livestock production keep pace with the needs of the Algerian population it is essential that there be multi-disciplinary production research that is amenable to both statistical and economic analysis. Proper coordination of research efforts is best ensured by having a single agricultural research organization working in the soil, plant, and animal sciences with supporting groups in economics, statistics and biometry, chemical analysis, entomology, plant pathology, etc. There is a great need for a well-staffed, production-orientated National Institute of Agricultural Research to undertake this multi-disciplinary research. This Institute should combine the existing National Institute for Agronomic Research in Algeria (INRAA) and the National Institute for Development of Animal Production (INDPA) and incorporate such groups as the Cereals Project and agricultural extension and information services. These coordinated activities should ensure greatly increased cereal and livestock production, proper integration of crop and livestock enterprises and a continuing improvement in the rural economy of Algeria.
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