



**Food
Legume
Improvement
and
Development**

Proceedings
of a
workshop
held at The
University
of Aleppo,
Syria,
2-7 May
1978

Geoffrey C.
Hawtin
and
George J.
Chancellor,
Editors

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IDRC-126e

Food legume improvement and development: proceedings of a workshop held at the University of Aleppo, Aleppo, Syria, 2-7 May 1978. Ottawa, Ont., IDRC, 1979. 216 p.:ill.

/IDRC publication/. Compilation of workshop papers on /legume/ /food production/ in the /Middle East/ and /North Africa/ — discusses agro/bio-climatology/ and /cultivation system/s, /nutrition/al value and /food composition/, /plant production/ (particularly of /chickpea/s, /lentil/s, and /faba bean/s), /agricultural research/, /cultivation practice/s for /plant protection/, /plant disease/s, /insect/ /pest/s, /disease resistance/, /weed control/ problems (use of /herbicide/s in /arid zone/s); /plant breeding/ and /genetic improvement/. /IDRC mentioned/, /list of participants/.

UDC: 633.3

ISBN: 0-88936-202-5

Microfiche edition available

35914

IDRC-126e

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Proceedings of a workshop held at
the University of Aleppo,
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Editors: Geoffrey C. Hawtin and George J. Chancellor

Published by the
International Center for Agricultural Research in the Dry Areas
and the
International Development Research Centre

The views expressed in this publication are those of the individual author(s) and do not necessarily represent the views of ICARDA or IDRC.

ARCHIV
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Contents

Preface	4
Foreword	5
Section I An Introduction to Food Legumes in the Region	
Some aspects of the agroclimatology of West Asia and North Africa Hazel C. Harris	7
Food legume production: the contribution of West Asia and North Africa to the world situation F.M. Hamawi	15
Food legumes in the farming system: a case study from Northern Syria David Gibbon and Adrienne Martin	23
Nutritional quality and importance of food legumes in the Middle Eastern diet Raja Tannous, Salah Abu-Shakra, and Abdul Hamid Hallab	29
Section II The Present Production and Improvement Situation	
Food legumes in Algeria Walid Khayrallah and Lounes Hachemi	33
Production and improvement of grain legumes in Egypt Ali A. Ibrahim, Abdullah M. Nassib, and Mohamed El-Sherbeeney	39
Food legume production in the Hashemite Kingdom of Jordan M. Abi Antoun and A. Quol	47
Food legume production and improvement in Iran M.C. Amirshahi	51
Food legumes in Iraq Mahmoud A. Mayouf	55
Food legume research and development in the Sudan Farouk A. Salih	58
Food legume improvement in Tunisia M. Bouslama and M. Djerbi	65
Food legume production and improvement in Lebanon R. Lahoud, M. Mustafa, and M. Shehadeh	69
Grain legume production in Turkey D. Eser	71
Food legume research and production in Cyprus J. Photiades and G. Alexandrou	75
Broad beans (<i>Vicia faba</i>) and dry peas (<i>Pisum sativum</i>) in Ethiopia Asfaw Telaye	80
Food legumes in Syria Sadek El-Matt	85
Food legume improvement in the People's Democratic Republic of Yemen Shafiq Mohsin Atta	88
Food legume production in Libya Ali Salim	90
Status of food legume production in Afghanistan N. Wassimi	91
Food legumes in India A.S. Tiwari	94
Section III Disease Problems on Legume Crops	
Diseases of major food legume crops in Syria S.B. Hanounik	98
Food legume diseases in North Africa M. Djerbi, A. Mlaiki, and M. Bouslama	103
Food legume diseases in Ethiopia Alemu Mengistu	106
Diseases of broad beans (<i>Vicia faba</i>) in the Sudan Mustafa M. Hussein and Sami O. Freigoun	109
Section IV Major Pests and Weeds of Food Legumes	
Insect pests of food legumes in the Middle East Nasri S. Kawar	112
Insect pests of chick-pea and lentils in the countries of the Eastern Mediterranean: a review G. Hariri	120
Some insect pests of leguminous crops in Syria Ara A. Kemkemian	124
The biology and control of <i>Orobanche</i> : a review A.R. Saghbir and F. Dastgheib	126
Broomrape (<i>Orobanche crenata</i>) resistance in broad beans: breeding work in Egypt Abdullah M. Nassib, Ali A. Ibrahim, and Hamdy A. Saber	133
Accentuation of weed control problems in the dry areas with relevance to herbicides in food legumes F. Basler	136

Section V Food Legume Development	
Genetic resources of grain legumes in the Middle East	
L.J.G. Van der Maesen	140
Strategies for the genetic improvement of lentils, broad beans, and chick-peas, with special emphasis on research at ICARDA	Geoffrey C. Hawtin
Some agronomic and physiological aspects of the important food legume crops in West Asia	M.C. Saxena
The role of symbiotic nitrogen fixation in food legume production	Rafiqul Islam
The ICARISAT chick-pea program with special reference to the Middle East	K.B. Singh
Methods of population improvement in broad bean breeding in Egypt	Abdullah M. Nassib, Ali A. Ibrahim, and Shaaban A. Khalil
Pollinating insects: a review	Ara A. Kemkemian
Section VI Cooperative Approaches to Food Legume Improvement at the National Level	
The training and communications program at ICARDA	S. Barghouti
FAO food legume programs in the Middle East and North Africa	Hazim A. Al-Jibouri and A. Bozzini
The food legume improvement and development program of the field crops section at ACSAD	L.R. Morsi
The role of IDRC in food legume improvement research	F. Kishk
Section VII Recommendations for Future Research Priorities	194
Bibliography	199
Participants	214

Some Agronomic and Physiological Aspects of the Important Food Legume Crops in West Asia

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The extent to which a plant can harness the natural resources of solar radiation, carbon dioxide, water, and other inorganic nutrients available to it in the production of yield is dependent upon its genetic composition. The genetic control of yield is achieved through regulation of the morphological structure of the plant and its physiological functioning. The genetic constitution of the plant thus determines its potential yielding ability, but the degree to which this potential is realized depends to a large extent on the environment in which it grows. Because the crop environment can be partly regulated by agronomic manipulations, the achievement of high yields, which is one of the main objectives of crop improvement work, demands that aspects of agronomic management be given active consideration alongside the genetic alteration of plant structure and functioning.

Lentils (*Lens culinaris*), chick-peas (*Cicer arietinum*), and broad beans (*Vicia faba*) are the three food legume crops of major importance to the agriculture of West Asia and North Africa. Their respective average productivity is reported to be 1068, 950, and 1872 kg/ha in the Near East and even lower in the Far East and Africa, as against maximum yields of 3500, 4400, and 7500 kg/ha, respectively, reported from experimentation. Quite a substantial part of this apparent gap between the potentially realizable and actually realized yield may be attributed to inadequate agronomic management.

With this background, the present paper briefly reviews the current state of knowledge on the agronomy and production physiology of the three food legumes with the aim of highlighting the importance of the various factors that affect yield and identifying areas requiring further research emphasis in the future.

Environmental Conditions

The temperature optima for the growth of lentils, chick-peas, and broad beans lies between 10 and 30 °C and the crops will thus grow at all locations where altitude and latitude permit these temperature ranges. All three crops, for instance, are grown extensively at low elevations between latitudes 15 and 40°N; and chick-peas are also produced between 0 and 15°N, but at higher elevations to meet the low temperature requirements; and broad beans may be cultivated up to 60°N at low altitudes and in close proximity to the sea.

Chick-peas, lentils, and to some extent also broad beans are subject to decreasing temperatures and day lengths immediately after planting in India, Pakistan, and some parts of North Africa, whereas they experience increasing temperatures and day length when grown in Iran, Syria, Jordan, Lebanon, Turkey, Italy, and Spain.

The soil moisture availability and stresses under which these crops are produced also vary considerably throughout the region, with the differences in rainfall pattern (and irrigation) and thermal regimes experienced. They are raised on conserved soil moisture in the Indian subcontinent and in parts of Iran and Turkey, while production in Egypt and Sudan is almost entirely irrigated. In Syria, Lebanon, Jordan, and adjoining areas, broad beans are grown exclusively under irrigation, except at high rainfall coastal locations, whereas chick-peas and lentils are produced mainly under rainfed conditions, the former on

residual moisture after the winter rains and the latter during the rains, but exposed to the desiccating atmosphere and moisture stress during flowering and crop maturity.

The environmental conditions under which these crops are produced can thus be seen to be very varied with respect to many aspects.

Lentils

Agronomic Requirements

Emergence

Lentils are ecologically well adapted to cooler environments, but are adversely affected by long and intense periods of frost. They are therefore grown as winter crops only in areas experiencing mild winters, and where winters are severe are usually spring sown. The optimum temperature for germination ranges between 15 and 25 °C, the rate of emergence being slower at the lower temperatures. Sowing at a depth of 4–5 cm has been found to ensure rapid emergence and a better dry matter production than either shallower or deeper planting. Greater delays in emergence have been observed with deeper plantings as soil temperature decreases and small-seeded cultivars appear to be more sensitive to deep planting than the larger ones. Varietal differences in the rate of emergence have been noted in preliminary studies at the ICARDA site in Syria during the 1977–78 season.

Date of Planting

The performance of lentils is affected markedly by planting date, the optimum time varying between locations. Under Indian conditions, the second half of October has been found to be the best time, but the highest yields achieved in Egypt have been obtained from planting in the first half of November. The optimum planting date in Karaj (Iran) was found to be in mid-March, but at higher elevations, planting generally takes place in late April or early May.

Delayed plantings invariably result in conspicuous yield reductions as a result of reduced vegetative growth and the early termination of growth and onset of senescence due to the rapid temperature rises experienced during the reproductive phase.

Plant Population

Responses of lentils to planting density have been highly variable and depend largely upon the growing conditions and the cultivar type. Many common cultivars exhibit a high degree of plasticity and therefore little yield differences have been obtained with large variations in sowing rate, particularly under conditions of adequate moisture supply and high soil fertility. However, a general trend for yield to increase with sowing rate has been observed by some researchers, a density of about 300–450 seeds per m² giving the highest yields. Such densities may be obtained with seeds spaced at 1.5–3 cm in rows 15–30 cm apart. Under conditions allowing only restricted vegetative growth (e.g., late sowing; under inadequate moisture conditions) or with cultivars possessing a lesser plasticity, narrower spacings and higher seed rates are recommended. This will enable the development of a closed leaf canopy, permitting optimum interception of incident radiation and resulting in higher yields. Based on calculations from seed density studies and a series of seed rate trials, rates of 60–80 kg/ha for small-seeded types and 160–200 kg/ha for the large-seeded varieties appear to be optimum for dryland areas.

Farmers over much of the region use higher seed rates than these, broadcast the seed, and then mix it into the soil with a country plough. This process converts the seedbed into a series of ridges and furrows and concentrates the seed in bands at the top of the ridges. Such a situation gives a suboptimal utilization of the space available and results in a high level of interplant competition. To avoid this yield-limiting problem, seeds may be drilled or planted into rows about 22.5–30 cm apart, without any subsequent cultivation.

Fertilizer Requirement

A lentil crop yielding 2 tonnes of grain per hectare may take up in the process about

95–100 kg of nitrogen per hectare. Under Egyptian conditions it has been reported that about 77% of this requirement could be satisfied through symbiotic nitrogen fixation. However, this level of performance will only be possible with very effective fixation. The need for inoculation with effective strains of *Rhizobium leguminosarum* has thus been emphasized and a consideration of host variety/rhizobium specificity is an important factor in such inoculations, as significant specificity has been recorded. Several studies have shown that applications of 20–30 kg N/ha are necessary as a starter to ensure the adequate nitrogen nutrition of the crop, despite the large contribution made by rhizobial nitrogen fixation.

Farmyard manure has been found to have a positive effect on the performance of lentils and is commonly recommended for lentil production in Pakistan.

The soils of many lentil-growing areas are characterized by a low available phosphorus status and economic responses have been obtained from phosphate application in India, Pakistan, Iran, Egypt, Syria, and Greece. The optimum rate varies from 40 to 100 kg P₂O₅ per hectare, depending upon the fertility status and phosphate fixation capacity of the soil. Studies on high pH, low phosphorus soils of Syria have revealed that an available P status of 4 ppm was required in the soil during periods receiving normal levels of rainfall, but that when precipitation was scarce, a range of 7–9 ppm was necessary for the highest yields. This work highlights the importance of phosphate fertilization in lentil crops, particularly during years of suboptimal rainfall.

In contrast to phosphate, positive responses to potassium application have been few. Significant yield increases have been obtained with applications of 22 kg/ha of K₂O in 2 years out of 3 on a sandy loam soil in the Punjab of India, but no responses have been obtained in Iran or Sudan. An improvement in the cooking quality of lentils has, however, been reported from K applications to the crop raised in pots and adequately supplied with other macro and microplant nutrients.

Studies on the response of lentils to micronutrient applications have, to date, been limited. Micronutrient deficiency problems are, however, likely to be encountered in the crop, because lentils are frequently grown under edaphic conditions where the availability of such nutrients is likely to be restricted. Lentils show a high susceptibility to zinc deficiency (fairly widespread on paddy rice soils in India and Pakistan) and, although varietal differences have been observed, most of the varieties show yield improvements from soil applications of 10–15 kg/ha of zinc sulfate or a foliar spray of 5 kg/ha of the chemical when deficiency symptoms are first evident. Experiments have shown the crop to exhibit deficiency symptoms when the P:Zn ratio was higher than 400 and the Fe:Zn ratio higher than 11 in the whole shoot. It has also been found that application of zinc at the rate of 5 ppm increased the survival of lentil rhizobia in the rhizosphere, decreased the P:Zn and Fe:Zn ratios in the lentil shoots, and increased the number, dry weight, and leg-hemoglobin content of root nodules, resulting in increased nitrogen fixation and dry matter yields in zinc-deficient soils. Positive responses have been obtained to molybdenum application in Bulgaria, increases of 15.5 and 17.5% in seed yield being obtained by soaking the lentil seed in ammonium molybdate solutions designed to provide an equivalent of 50 and 100 g Mo/ha. Although some workers failed to achieve a response through foliar spraying, others have reported increased yields, crude protein contents, and phosphate uptake through sprays of the chemical at concentrations of 0.01, 0.02, and 0.04% and a rate of 60 litres/ha.

Water Management

Under adequate moisture conditions, lentils are known to use water at least as luxuriously as cereal crops. The transpiration ratio appears to vary with region and variety, ranging between 200 and 500 in the humid region and from 800 to 1500 in the semi-arid region. Growth chamber studies have revealed that leaf area and dry matter production increase with increasing irrigation frequency, and positive responses have also been obtained in the field. The crop is, however, very sensitive to overwatering and yield reductions will occur if irrigation is excessive. Flowering appears to be a critical growth stage for water supply and delaying irrigation beyond this stage has been shown to cause yield reductions.

In general, lentils, however, are grown as a rainfed crop. In the Indian subcontinent, where they are produced on residual moisture, the moisture conserved from late rains in the monsoon season determines crop performance, whereas in the Mediterranean-type climate the yield depends largely upon the rains received during the period December to March. In both cases irrigation is rare.

Weed Control

Morphologically lentils are at a disadvantage with respect to competition with weeds, and yield reductions of up to 75% have been reported as a result of weed infestations. Weed competition is most serious in winter crops between 30 and 60 days after crop emergence in areas with mild winters and between 60 and 90 days after emergence where the winter conditions are more severe. Mechanical weed control during this period has proved an effective and economical method under Indian conditions and has generally been superior to the use of herbicides. Results of tests on several herbicides applied at different crop stages have indicated some promising chemical control methods: trifluralin, when used as a preplant-incorporated herbicide, has proved good under adequate moisture conditions although tolerance to this chemical is generally low in the crop; and linuron, prometryne, and dosanex have shown promise as preemergence herbicides. Considerably more herbicide screening, especially on the basis of toxicity to weeds and crop tolerance, is now necessary to evolve appropriate chemical weed control for the dryland production of lentils.

Harvesting

The conventional method of lentil harvesting involves the hand pulling of plants before they are completely dry to avoid pod shattering. However, considerable yield losses still occur, particularly during the gathering and transporting of the plants after they have been field dried in the sun.

Mechanical harvesting, which is already practiced in the United States, is becoming an increasingly urgent consideration in West Asia as a result of the declining availability and consequently increasing cost of hand labour at harvesting. However, the generally short plant stature and susceptibility to lodging evident in currently grown varieties poses a great problem to the introduction of this technology. The development of taller varieties with stronger stems is thus an obvious way to facilitate mechanical harvesting and in turn reduce harvesting losses. Experiments have indicated that some height increase may be obtained in lentil by sprays of gibberellic acid, but more studies on this aspect are necessary before it could be put into practical use. Investigations have shown that *Camerlina* spp. and yellow mustard in mixture with lentils help to prevent lodging and facilitate harvesting, but such a technique appears to have only limited applicability.

Physiological Aspects

Although lentils have frequently been used in biochemical studies, work on their physiology has been limited. Additional information on the physiological aspects of the crop will assist in understanding the reasons for the adaptability of existing cultivars to rather narrow agroecological regions and in the development of genotypes with a wider adaptability.

Photoperiodic and Vernalization Requirements

Lentils are sensitive to photoperiodic conditions and are classed as "long day" plants. Genotypes may, however, differ, some showing "quantitative" requirements whereas others behave as "qualitative long day" plants.

Vernalization studies involving the exposure of soaked seeds to a temperature of 6 °C for about 5 weeks have shown that lentils respond to vernalization by a hastening of flowering and a reduction of the period of vegetative growth.

Salt, Drought, and Heat Tolerance

Stress from salinity, drought, and heat causes a considerable reduction in the productivity of lentil crops. This stress varies appreciably with season and climate and the development of varieties tolerant to these conditions may lead to real increases in the yield stability.

A 50% reduction in the germination of lentils was observed at a soil conductivity of 20 mmhos/cm, whereas yield reductions of 50% occurred at 3.9 mmhos/cm conductivity level. Investigations on two varieties have shown the salt tolerance limit to lie between 8.4 and 13.1 mmhos/cm conductivity and conspicuous reductions in dry matter yield to occur beyond 5.0 mmhos/cm. The cultivar Large Blonde was found to tolerate salinity better than Anicia, the other cultivar tested.

Differences in tolerance to drought have also been observed between cultivars: white lentils from Syria appear to be more tolerant than the red lentils from Egypt; and evaluations of 100 genotypes near Sofia (Bulgaria) have indicated that large-seeded types, with their longer growing period, are less tolerant to drought than small-seeded cultivars.

Canopy Development and Photosynthesis

The mean crop growth rate is very low in the early vegetative phase, particularly at low temperatures. However, there are indications that genetic differences exist in the rate of canopy development and dry matter production under such conditions. Total dry matter production and grain yield have been found to be very highly correlated with the degree of interception of photosynthetically active radiation during the pod-filling stage, a closed canopy, permitting 90% interception of incident radiation at the flowering period, giving the highest yields. Canopy closure is dependent upon the branching pattern and leaf area development. Genotypes can be seen to differ appreciably in both these characters and in the degree to which they are expressed in differing environments. Genotypic differences have also been observed in the photosynthetic rate and the partitioning of dry matter into different components of yield. Such a variability means that the potential for evolving more productive genotypes, in terms of dry matter as well as economic yield, is considerable.

Growth Regulation

Seed treatment with growth regulators, such as indoleacetic acid and indolebutyric acid have been demonstrated as affecting the rate of seedling establishment and early growth. The role of growth regulators in modifying the canopy structure and productivity of lentil has also been investigated. Under conditions of late planting, permitting restricted plant growth, significant increases in lentil yield have been recorded following a foliar spray of a 20-ppm solution of the sodium salt of naphthyl acetic acid 50 days after planting. High rates of applications of 2,3,5-Triiodobenzoic acid, however, resulted in reduced yields in one lentil cultivar through the production of an intertwined canopy. The role of growth regulators and antitranspirants on drought tolerance and water use economy still remains to be established.

Chick-peas

Agronomic Requirements

A general review of the agronomic requirements of chick-peas has previously been carried out as have agronomic studies under Indian conditions (Saxena and Yadav 1976; Van der Maesen 1972). The present coverage is therefore mainly restricted to work in West Asia and North Africa.

Planting Date

Chick-peas produced in the region may be planted from early winter to late spring, depending upon the location. It has been observed in studies of plantings from 16 August to 20 October that delayed sowing results in reduced growing, preflowering and flowering periods, and a considerable depression of plant development, leading to drastically reduced

yields. Studies in Sudan have established the optimum planting time as late November to early December; earlier as well as later plantings result in appreciable yield reductions. At lower elevations in Iran, the highest yields have been obtained from October plantings, but at higher elevations autumn plantings have led to winter injury and thus chick-peas are generally spring sown, early April proving to be the best time in Karaj and late April–early May being the optimum at Tabriz. In general, the winter temperatures over much of the Mediterranean region are not sufficiently severe to cause damage to autumn-sown chick-peas. However, most farmers still adhere to spring plantings and the subsequent exposure to moisture stress and high temperatures during the early phase of reproductive growth, which result in reduced yields. This is primarily because, despite the higher yields that can be obtained from autumn planting, the incidence and destructiveness of *Ascochyta* blight is considerably increased and total crop loss often results. The development of genotypes suitable for winter planting (i.e., with cold tolerance and tolerance or resistance to *Ascochyta* blight) will thus fulfill a great need and enable very great yield increases in this crop.

Plant Population

Optimum plant population appears to depend very much on growing conditions, especially moisture supply. Investigations undertaken over a 3-year period in Karaj (Iran) with irrigated chick-peas have shown that yield increases with plant population, the highest yields being obtained with 0.5 million plants per hectare. Subsequent studies at Tabriz have confirmed this trend under irrigated conditions and have indicated lower populations (about 0.248 million plants/ha) to give the highest yield in rainfed crops. Information is currently required on optimum plant populations and planting geometry for genotypes with different growth habits and planted at different seasons in the Mediterranean-type climates.

Fertilizer Use

The removal of plant nutrients by a chick-pea crop yielding about 3 tonnes of grain and 4.5 tonnes of straw per ha has been estimated to be approximately 144 kg N, 31 kg P₂O₅ per ha. It has also been estimated that 100 kg N/ha, or 77% of the total nitrogen content of the crop, is annually supplied through symbiotic fixation under Egyptian conditions. The contribution of symbiosis to total nitrogen yield in the crop probably varies with host genotype, rhizobial strain, and environmental conditions. Under favourable conditions, therefore, symbiotic fixation could account for almost all of the crops' nitrogen requirements, as was probably the case in studies carried out in India and Iran as part of the Regional Pulse Improvement Project, which showed no large-scale responses to nitrogen fertilization. However, other experiments in Sudan have shown positive responses to increasing applications of nitrogen (up to 120 kg/ha in irrigated crops). Split applications (one-half at sowing and one-half at flowering) were found to be best in these cases, particularly at intermediate levels of fertilization (80 kg/ha). Poor nitrogen status of the soils and the lack of nodulation (possibly due to salinity) were considered to be responsible for this positive response and the need for inoculation with effective strains of *Rhizobia* was emphasized under such conditions. The use of solid inoculant in the furrow, rather than the slurry inoculation of the seeds after treatment with Cerasan fungicide, has been recommended as the key to good nodulation.

No response to the application of either phosphorus or potassium could be obtained in experiments at Karaj, and investigations on phosphorus-deficient soils at ICRISAT (India) have also failed to obtain yield increases from phosphorus applications. The reasons for this apparent lack of response must be investigated. Perhaps this will lead to a revision of the standards of deficiency and sufficiency levels and the development of improved methods of assessing the availability status of phosphorus in soils. Chick-peas are known to have a high sulfur requirement and responses to applications of sulphur also warrant future studies.

Only limited studies have been conducted on crop response to micronutrients to date. Iron deficiency symptoms have been observed in some chick-pea cultivars when grown on highly calcareous soils in Lebanon and Syria, although the majority of the locally grown

cultivars showed no such problems. This deficiency may be easily corrected by foliar sprays of a 0.5% solution of ferrous sulfate, but care should be taken to ensure that the trait for more efficient iron utilization is retained in genotypes being bred for calcareous soils. Zinc deficiency has also been observed in chick-peas and varietal differences in susceptibility have been recorded and may be used in breeding programs, although the deficiency can be corrected by spraying zinc sulfate (0.5% solution).

Water Use

The water requirement (i.e. transpiration ratio) of chick-peas is reportedly as high as 1000. In most parts of the region this requirement must be met from moisture conserved in the soil profile from the preceding rainy season. If this conserved moisture is insufficient to the needs, the crop responds well to supplementary irrigation. Studies at Shiraz (Iran) have shown a 6-day irrigation interval to give yields almost twice as great as with irrigations every 9 days. A higher irrigation efficiency was obtained with basin irrigation (45.4%) as opposed to furrow irrigation (35.5%), although this had no effect upon yield. The greatest yield response in work at Karaj has been achieved by irrigation at the prebloom stage every time the soil moisture fell to 33% of field capacity, and during the period after full bloom every time the level reached 66% of field capacity. Field experiments conducted in Sudan have given the best results with a 14-day irrigation interval; more or less frequent irrigations depress the yields.

Urgently needed at the present time are agronomic methods designed to increase the conservation of moisture in the soil profile in the preplanting period and to reduce its loss during crop growth. Such methods will greatly increase the efficiency of the use of moisture received through precipitation.

Weed Control

Although better competitors than lentils, chick-peas also suffer from weed competition. Screening for suitable herbicide control measures is currently under way at ICARDA and detailed studies are now required to devise an effective system of weed management through a combination of cultural and chemical methods.

Harvesting

The need for mechanization of harvesting is widely recognized in this crop, as in lentils, throughout the region. The effects of various cultural practices on harvest loss in chick-peas must be investigated and breeding work should emphasize the development of taller plants with a more upright growth habit.

Physiological Aspects

Germination

Although germination may be obtained at temperatures as low as 10 °C and as high as 40 °C, the optimum soil temperature for germination appears to lie between 25 and 35 °C. At lower temperatures the time lag before germination increases; with decreasing temperatures the crop emergence is decreased; and no emergence occurs at soil temperatures above 44 °C.

Photoperiodic and Vernalization Responses

Chick-peas seem to be sensitive to photoperiod and to respond to vernalization. This may be partly responsible for the observed adaptability of genotypes to rather specific locations. Although chick-peas have been generally found to be "long day" plants, some genotypes appear to flower under day lengths as low as 8 hours. Such genotypes may be less sensitive to photoperiod and thus have considerable potential for use in breeding efforts designed at achieving wider adaptability. Flower bud initiation and flower development have been shown to be hastened by long day conditions and the effect of vernalization to complement this.

Salinity Tolerance

Chick-peas are highly sensitive to salinity, irrigation with water of a conductivity of 10 mmhos/cm reducing yield by as much as 55%. The development of salt-tolerant genotypes is thus a priority consideration for areas where the crop is grown under irrigation and the water tends to be brackish. In addition, because root nodule function seems relatively insensitive to salinity after establishment, special inoculation methods should be developed to enable successful establishment of *Rhizobia* with the host roots under saline conditions.

Drought, Heat, and Frost Tolerance

As most chick-peas are grown on conserved moisture, the rooting pattern may be an important determinant of crop performance. Genotypic differences in rooting pattern are evident and such differences may thus be of use in the development of varieties with some tolerance to drought and hence greater yield stability. However, the effective use of this character in varietal improvement work requires that a quick technique be developed for screening genotypes for their potential root growth.

Tolerance to high temperature during reproductive growth would also be a very desirable character for crop production in the drier areas. The double pod character (two pods per peduncle rather than the usual one) has been reported to express itself well under the adverse conditions that tend to shorten the flowering period. This character may prove very useful in the breeding of more stable varieties for production under these conditions.

Frost tolerance is also a desirable character for the development of high-yielding varieties for the high elevation plateau areas of the region, where spells of frosty weather are likely to occur during seedling establishment and early vegetative growth.

Photosynthesis

Chick-peas possess considerable genetic variation in their photosynthetic rates. The rate of photosynthesis normally decreases sharply with the onset of flowering, although varietal differences in this respect were also conspicuous.

Photorespiration is responsible for considerable losses of photosynthate and the temperature conditions under which reproductive growth takes place in the region tend to increase this process and thus reduce net carbon gain by the crop. The identification of genotypic differences for a more efficient photosynthetic system, reduced photorespiration, and higher nitrogenase activity during reproductive growth should thus greatly increase the potential for developing more productive cultivars.

It has been shown in some cultivars that photosynthesis in the pod wall may make a significant contribution to the carbon pool in the developing seed. Although studies have shown that the "exposed pod" character does not seem to confer an advantage to a genotype, its importance needs to be further examined with a wider range of genotypes and environmental conditions before any firm conclusions can be drawn.

Broad Beans

Agronomic Aspects

Agronomic studies of the broad bean crop have been carried out fairly extensively in Egypt and Sudan where production is under irrigation, but little published information is available from other parts of the region.

Date of Planting

Experiments conducted over a 3-year period and at a number of different locations in Egypt have revealed that 15 October–1 November is the best planting date for broad beans. Similar and subsequent studies with improved varieties in Sudan have confirmed these findings. Varietal differences in yield reduction with delay in planting were conspicuous.

Plant Population

Yield per unit area has been reported to reach a maximum at a plant density of 35–45

plants/m² in winter types and at 67 plants/m² in spring cultivars. It has also been found that, for a given density, alterations in the between-row distance had little influence on plant development. Studies in Sudan have shown that yield increases with seed rate between 83 and 166 kg/ha, but that seed rates beyond 332 kg/ha caused yield reductions. Within this range it appears that closer row spacings and higher plant populations tended to result in higher yields; the plants, however, showed considerable compensatory mechanisms between their yield components, so that large variations in density caused relatively small yield differences. Similar results have been obtained from investigations in Egypt, where varietal and locational differences have also been detected; a row spacing of 30 cm and a hill spacing of 15 cm (with two plants per hill) gave much greater yield increases over spacings of 60 and 20–25 cm, respectively, in Middle Egypt than in the Nile Delta region. Egyptian studies have established the optima for seed rate at 140–180 kg/ha and studies in Ethiopia at a field spacing of 20 × 15 cm.

Fertilizer Use

Broad bean is known to fix more atmospheric nitrogen than either lentils or chick-peas. Estimates of N fixation under Egyptian conditions are about 135 kg/ha, which may account for approximately 70% of the total N content of the plant. The contribution of symbiotic nitrogen to total plant nitrogen may vary with soil N content and rates of fertilizer N application. Positive responses have been obtained to inoculations with suitable rhizobial strains. Broad bean yields have been increased by 10–12% with the application of 18 kg of inorganic N/ha, but in these studies no further response was obtained with applications over 36 kg/ha. However, good responses have been found from 42 kg N/ha applications in Sudan, particularly when fertilization was delayed until 2 months after planting or split into three dressings (33% at planting, 33% after 1 month, and 33% after 2 months).

Conspicuous responses to phosphorus applications have been observed in Egypt and rates of 72 kg P₂O₅/ha are recommended. Foliar application has been reported as better than applying the fertilizer to the soil in northern Sudan.

Positive responses to fertilization with potassium have been found outside the region but no reports of responses are available from within West Asia and North Africa. The favourable effect of potassium upon nodulation and symbiotic nitrogen fixation is well known and there is thus a need to study the importance of fertilization with this nutrient chemical in broad bean production in the region.

Studies on crop response to micronutrient applications are also limited and little information is available from the region. However, an application of molybdenum has been shown to improve the symbiotic nitrogen fixation and nitrogen nutrition of broad beans on a soil containing 0.18–0.29 mg Mo/kg.

Water Management

The transpiration ratio of broad beans has been reported to vary with climatic conditions, being 282 in Germany as against 736 in Colorado (USA) and, in both cases, higher than the corresponding values for wheat.

Water stress has been shown to reduce the absolute growth rate of leaf area and thus overall vegetative growth in broad beans. This effect is also extended into a significant reduction of grain yield. In addition, nitrogen fixation appears to be very highly correlated with the available moisture content of the soil. Studies have illustrated that the yield of broad beans is 80% higher under a "wet" regime (involving nine irrigations in both the vegetative and reproductive phases) than under a "dry" regime (with only six irrigations). These studies also revealed that it was better to maintain a wet regime during vegetative growth followed by a dry one from flowering to pod development, rather than vice-versa, but they were unable to pinpoint the critical stages very precisely. No significant responses to irrigation were obtained in Lower Egypt because of the rainfall, but between four and six irrigations were needed for good crop performance in the drier areas of Middle and Upper Egypt. Higher irrigation frequencies have also been reported to suppress infection by the very damaging parasitic weed *Orobanche*.

Excessive water supply can damage the broad bean crop. It is known, for example, that a water table at 5 cm below the soil surface can result in rotting of the seeds. The water management of this crop must thus be very good to prevent either prolonged periods of moisture stress or water logging.

Physiological Aspects

Germination

Germination rate has been found to increase as night temperature is raised from 5 to 20 °C with a constant daytime temperature of 20 °C. Highest seed yields were obtained when the night temperature was held at 10 °C.

Photoperiodic and Vernalization Response

Broad bean cultivars appear to behave either as long day or day neutral plants and showed some response to vernalization. Quantitative long day responses have been observed and flower initiation may be hastened by increasing the day length from 6 to 16 hours or a brief exposure of the plant to low temperatures (10 °C proving better than 4 °C in this respect). Such low temperature treatment may serve to overcome a reaction inhibitory to flower initiation that has been observed at temperatures above 14 °C during the flower initiation period. Vernalization of broad bean seed has also been found to be possible on the mother plant itself and this treatment leads to more rapid development of plants derived from treated seed.

Plant Ideotype

Most of the conventional varieties of broad bean are "top heavy" and tend to lodge under favourable growing conditions. It appears that only a fraction of the total leaf canopy is responsible for the interception of most of the incident light and therefore there is considerable mutual shading, a theory well borne out by the observation that precision planting gives much higher yields than normal drilling and that seed number and seed yield per plant increases linearly with the increase in available space from 200 to 500 cm² per plant. The development of a more open canopy with a terminal bud culminating in an inflorescence has been suggested as a means to evolve a more efficient plant type. Investigations are currently under way into this aspect at several locations using a topless mutant from the variety Primus, developed in Sweden.

Of the different contributory characters to yield in broad bean, it has been reported that the number of pods/plant was most important and that this was regulated more by the number of pods/node than by the number of nodes forming pods. An analysis of the relations between number of podded nodes/plant, pods/podded node, seeds/pod, and seed weight has revealed slightly negative correlations or no relations at all. From these studies it was concluded that the number of podded nodes/plant was the most important yield-determining character, although under adverse conditions the reduction in this character could be compensated for by an increase in the number of pods/node. There is an obvious need for more detailed examination of the role of these characters as they affect yield under conditions of scarce moisture supply and heat stress.

In general, the varieties grown in the Mediterranean area are more branched than those cultivars grown in Europe. This character may be important in stabilizing the yield of the crop in dry areas and requires further investigation.

Flower Drop

The loss of flowers and young pods may be substantial in broad beans: it has been reported, for example, that 86.7% and 93.7% of the buds produced by the varieties Baladi and Giza 1 were lost from flower and young pod drop. Dropping apparently starts at the lower internodes and progresses upward and intra- and interinflorescence competition between the young pods leads to drops from the nonpreferred positions. This problem may be compounded in the indeterminate types, where vegetative growth continues for a long period and overlaps with reproductive growth. It appears that the younger fruits have to

overcome a lag phase and only when sufficient photosynthates are available can more young fruits begin to develop. It should thus be possible to increase yield by reducing competition between vegetative and reproductive growth through breeding, treatment with growth regulators, or detopping. Other possible reasons have also been suggested for flower drop apart from the deficiency of assimilates for the developing reproductive sink. These include: nitrogen supply; hormonal factors; gaseous exchange; temperature and humidity in the canopy; mineral nutrient supply; and soil moisture. One or more of these factors may well be responsible for flower shedding and it is thus necessary to identify the prime causes to permit eventual regulation of fruit set and yield.

The productivity of the three major legume crops produced in West Asia can thus be seen to be considerably affected by a very large number of physiological and agronomic factors, which limit both the yield potential and the degree to which this genetic potential is expressed in the production of the crops. A deeper and more comprehensive understanding of the physiological mechanisms that enable survival and determine yielding ability under the harsh dryland conditions of the region will provide a much more solid and logical base to breeding efforts designed to produce cultivars better able to exploit these environments. In addition, to ensure that these cultivars actually result in the improved yield for which they have the potential under field conditions, studies of crop agronomy must figure very highly in the overall strategy for their improvement.

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