Chickpea Botany and Production Practices

Compiled by

Faujdar Singh and B. Diwakar

Skill Development Series no. 16

ICRISAT

Training and Fellowships Program

International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

1995

Chickpea Botany and Production Practices

Compiled by

Faujdar Singh and B. Diwakar

Skill Development Series no. 16

ICRISAT

Training and Fellowships Program

International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

1995

Training and Fellowships Program

Publications in this Skill Development Series (SDS) are issued semiformally for limited distribution to program participants, colleagues, and collaborators. Copies may be requested by the SDS number. Constructive criticism from readers is welcomed by the Program Leader, Training and Fellowships Program, ICRISAT.

Acknowledgments

Information has been compiled from published and unpublished reports. The mention of trade names (®) of any chemical(s) does not constitute endorsement of, or discrimination against, any product by ICRISAT or by the authors. This publication should not be cited as a reference.

Comments and suggestions from Dr H.A. van Rheenen, Dr N.P. Saxena, Dr R.P.S. Pundir, and Dr N.B. Singh for compiling this document are gratefully acknowledged. Thanks to Mr S.V. Prasad Rao for processing this publication.

Contents

Introduction

Chickpea [*Cicer arietinum* (L.)] belongs to genus *Cicer,* tribe Cicereae, family Fabaceae, and subfamily Papilionaceae. It originated in southeastern Turkey (Ladizinsky 1975). The name *Cicer* is of Latin origin, derived from the Greek word 'kikus' meaning force or strength. Duschak (1871) traced the origin of the word to the Hebrew *'kirkes',* where *'kikar'* means round. The word *arietinum* is also Latin, translated from the Greek *'krios',* another name for both ram and chickpea, an allusion to the shape of the seed which resembles the head of a ram (Aries) (van der Maesen 1987). Chickpea is also called garbanzo (Spanish), pois chiche (French), kichar or chicher (German), chana (Hindi), and gram or Bengal gram (English). In Turkey, Romania, Bulgaria, Afghanistan, and adjacent parts of Russia, chickpea is called 'nakhut' or 'nohut' (van der Maesen 1987).

Area and Production

Chickpea is grown over an area of nearly 10 million ha in the world with a production of 7.1 million tons and productivity of 706 kg ha^{-1}. The major chickpea-producing countries of the world (Table 1) are India (68%), Turkey (11%), and Pakistan (8%).

Table 1. Area, production, and yield of chickpea in the world (average of 1989-91).

Country	Area ('000 ha)	Production ('000 t)	Yield (kg ha')
Algeria	50	18	364
Bangladesh	102	67	655
Egypt	6	11	1833
Ethiopia	130	114	877
India	6897	4847	703
Iran	120	49	411
Iraq	5	3	600
Jordan	2	1	571
Lebanon	4	5	1250
Morocco	73	55	758
Myanmar	129	97	749
Nepal	28	17	607
Pakistan	1023	534	522
Sudan	2	1	667
Syria	49	26	524
Tunisia	55	30	539
Turkey	850	801	943
World	10078	7116	706

Source: FAO production tapes, 1992.

Botany

Plant Habit

Chickpea is a herbaceous annual plant which branches from the base. It is almost a small bush with diffused, spreading branches. The plant is mostly covered with glandular or nonglandular hairs but some genotypes do not possess hair.

Based on seed size and color, cultivated chickpeas are of two types (Cubero 1975).

1. **Macrosperma *(kabuli* type).** The seeds of this type are large (100-seed mass >25 g), round or ramhead, and cream-colored. The plant is medium to tall in height, with large leaflets and white flowers, and contain no anthocyanin.

2. **Microsperma *(desi* type).** The seeds of this type are small and angular in shape. The seed color varies from cream, black, brown, yellow to green. There are 2-3 ovules pod^{-1} but on an average 1-2 seeds pod^{-1} are produced. The plants are short with small leaflets and purplish flowers, and contain anthocyanin.

Seed and Germination

Chickpea seeds have a seed coat, two cotyledons, and an embryo (Fig. 1a). The seed coat consists of two layers, the outer testa and the inner tegmen, and a hilum. The hilum is the point of attachment of the seed to the pod. There is a minute opening above the hilum called the micropyle, and a ridge formed by the funicle called the raphe. The embryo consists of an axis and two fleshy cotyledons (Fig. 1b to d). The pointed end of the axis is the radicle and the feathery end the plumule.

Chickpea seeds germinate at an optimum temperature (28-33°C) and moisture level in about 5-6 days. Germination begins with absorption of moisture and swelling of the seed. The radicle emerges first followed by the plumule (Fig. 1e to i). The portion of the axis above the cotyledon called the epicotyl, elongates and pushes the plumule upward. The growth of the plumule produces an erect shoot and leaves, and the radicle grows to produce the roots. The first true leaf has 2 or 3 pairs of leaflets plus a terminal one (Fig. 1j). The plumular shoot and lateral branches grow continuously to develop into a plant (Cubero 1987).

Root

Chickpea plants have a strong taproot system with 3 or 4 rows of lateral roots. The parenchymatous tissues of the root are rich in starch. All the peripheral tissues disappear at plant maturity, and are substituted by a layer of cork (Cubero 1987). The roots grow 1.5-2.0 m deep. Chickpea roots bear *Rhizobium* nodules (Fig. 2). They are of the carotenoid type, branched with laterally flattened ramifications, sometimes forming a fanlike lobe (Corby 1981).

Stem

The chickpea stem is erect, branched, viscous, hairy, terete, herbaceous, green, and solid. The branches are usually quadrangular, ribbed, and green. There are primary, secondary, and tertiary branches (Cubero 1987).

Primary branches arise from the ground level as they develop from the plumular shoot as well as the lateral branches of the seedling. They are thick, strong, and woody, and may range from one to eight in number.

Secondary branches develop at buds located on the primary branches. They are less vigorous than the primary branches. Their number ranges from 2 to 12. The number of secondary branches determines the total number of leaves, and hence the total photosynthetic area.

Tertiary branches arise from the secondary branches.

The primary branches form an angle with a vertical axis, ranging from almost a right angle (prostrate habit) to an acute angle (erect). Generally stems are incurved at the top, forming a spreading canopy.

Leaves

Chickpea leaves are petiolate, compound, and uniimparipinnate (pseudoimparipinnate). Some lines have simple leaves. The rachis is 3-7 cm long with grooves on its upper surface. Each rachis supports 10-15 leaflets each with a small pedicel. The leaflets do not end at the true terminal position (the central vein continuing the rachis) but at the subterminal position (the central vein oblique to the rachis). This indicates the presence of two terminal leaflet buds, one of them being aborted or transformed into a mucro or foliar shoot which is sometimes quite large (Cubero 1987).

The leaflets are 8-17 mm long and 5-14 mm wide, opposite or alternate with a terminal leaflet. They are serrated, the teeth covering about two-thirds of the foliar blade. The shape of the leaflets is obovate to elliptical with the basal and top portions cuneate or rounded. Leaves are pubescent.

Stipules

The stipules are ovate to triangular in shape and serrated (2-6 teeth). They are 3-5 mm long and 2-4 mm wide. The longest margin is toothed and the smaller one entire (Cubero 1987).

Pubescence

The external surface of the chickpea plant, except the corolla, is densely covered with glandular or nonglandular hairs. The hairs vary in form and dimension: short stalked, multicellular stalked (both glandular and nonglandular), and unicellular. Some genotypes, however, do not possess any hair.

Inflorescence

The solitary flowers are borne in an axillary raceme. Sometimes there are 2 or 3 flowers on the same node. Such flowers possess both a peduncle and a pedicel (Fig. 2). The racemose peduncle is 6-30 mm in length. At flowering, the floral and racemal portions of the peduncle form a straight line, giving the appearance that the flowers are placed on the leafy axil by a single peduncle. After fecundation the raceme is incurved. The bracts are 1-5 mm in length.

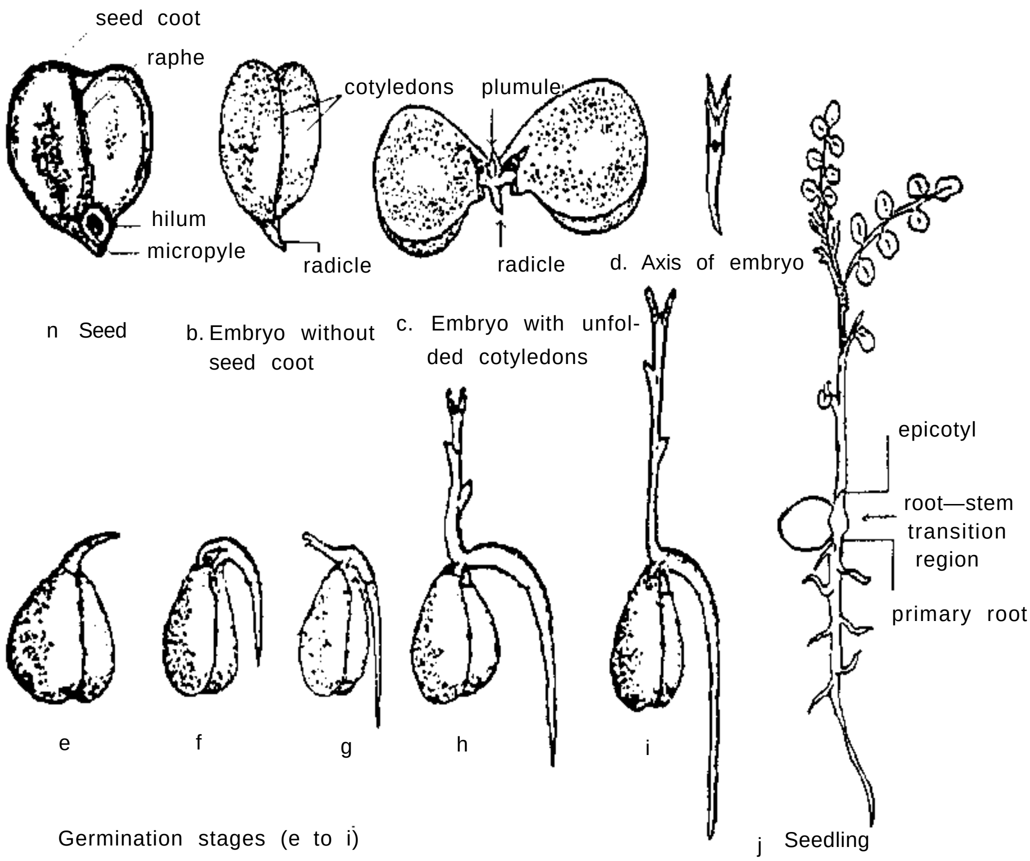

Figure 1. Chickpea seed and its germination.

Flowers

Chickpea flowers are complete and bisexual, and have papilionaceous corolla. They are white, pink, purple or blue in color. In colored flowers, the peduncles may be of different colors, the floral part purplish and the racemal green. The axillary inflorescence is shorter than the subtending leaf (Cubero 1987).

Calyx

The calyx is dorsally gibbous at the base. There are five sepals with deep lanceolate teeth (Fig. 3a). The teeth are longer (5-6 mm) than the tube (3-4 mm) and have prominent midribs. The five sepals are subequal. The two dorsal (vexillar) sepals are closer to each other than they are to the two lateral ones in the ventral position. The fifth calyx tooth is separate from the others. The peduncles and the calyx are glabrous. The calyx tube is oblique.

Corolla

Chickpea flowers have five petals which are generally celeste and purplish red or light pink in color. The petals are polypetalous i.e., consisting of standard (vexillum), wings, and keel (Fig. 3b). The vexillum is obovate, 8-11 mm long, 7-10 mm wide, and either glabrous or pubescent with no glandular hair on its external surface. The wings are also obovate with short pedicels (nails). They are 6-9 mm long and about 4 mm wide with an auriculate base. The auricula are over the pedicel and form a pocket in the basal upper part, which is covered by the vexillum. The keel is 6-8 mm long, rhomboid, with a pedicel 2-3 mm long. Two-thirds of the frontal side of its ventral face is adnate. The wings do not show concrescence with the keel.

Androeclum

There are 10 stamens in diadelphous (9)+1 condition (Fig. 3d,e). The filaments of nine of the stamens are fused, forming an androecial sheath; the tenth stamen is free. The staminal column is persistent. The fused part of the filament is 4-5 mm long and the free part 2-3 mm, upturned, and dilated at the top. The apex of the sheath is oblique.

The stamens facing the petals are a little longer than the others. The anthers of these stamens are bicelled, basifixed, and round. The other anthers are dorsifixed, ovate, and longer than the basifixed ones at flowering. The anthers burst longitudinally. The pollen grains are orange.

Gynoeclum

The ovary is monocarpellary, unilocular, and superior, with marginal placentation. It is ovate with a pubescent (glandular hairs predominate) surface. The ovary is 2-3 mm long and 1-15 mm wide. There are 1-3 ovules, rarely 4. The style is 3-4 mm long, linear, upturned, and glabrous except at the bottom (Fig. 3c). The stigma is globose and capitate. Sometimes it may be of the same size as the style (Cubero 1987).

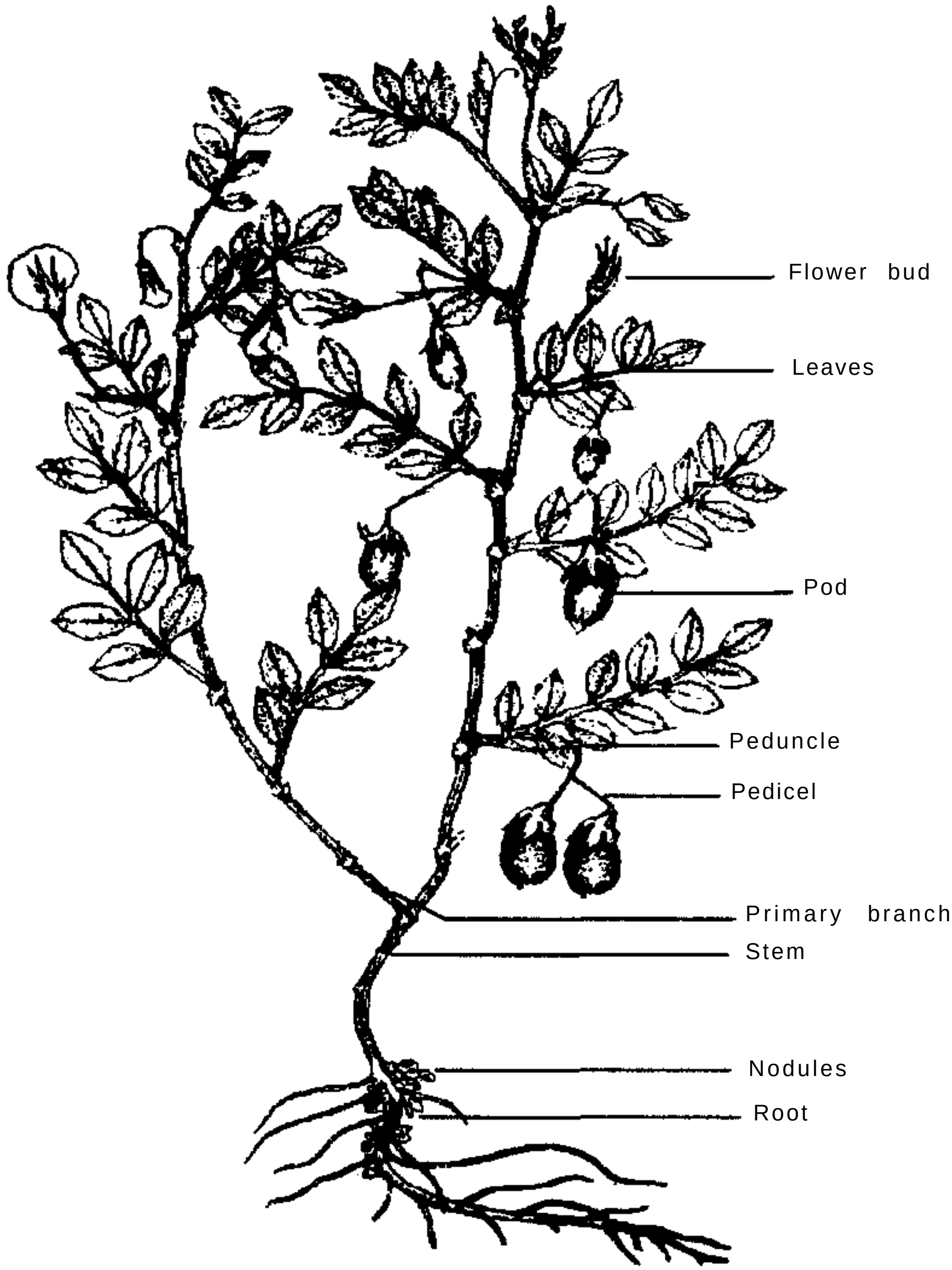

Figure 2. A typical chickpea plant.

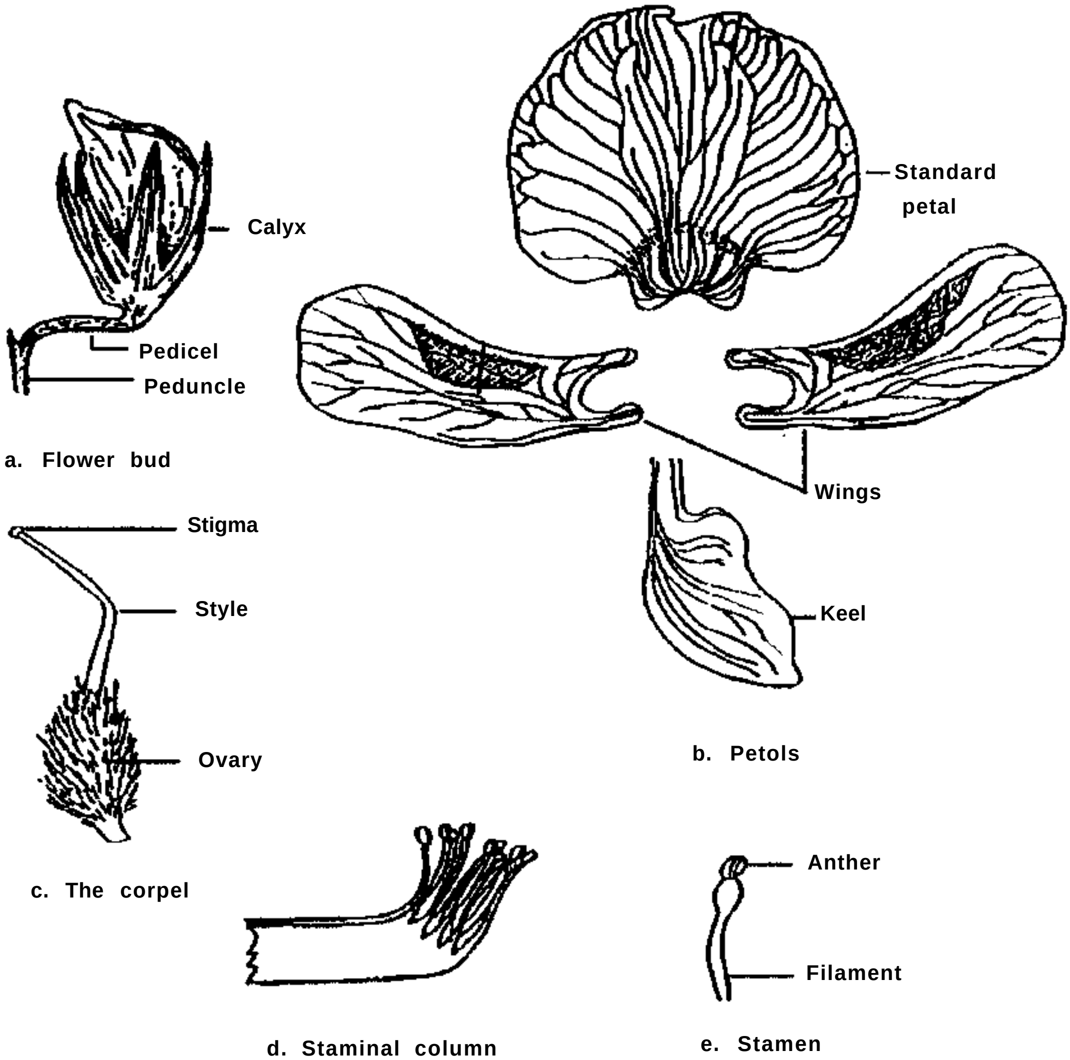

Figure 3. Parts of a chickpea flower.

Developmental Stages of the Bud and Flower

Eshel (1968) identified five stages of development of the bud and flower in chickpea.

a. **Closed bud.** At this stage, the stigma is immature and the anthers are still at the base of the bud.

b. **Hooded bud.** The corolla has elongated, and the anthers are about half the height of the style. The stigma is receptive. Emasculation is done at this stage.

c. **Half-open flower.** At this stage the anthers attain the same height as the stigma, and the pollen mature just before the dehiscence of the anthers. Self-pollination takes place at this stage while the keel petal remains closed, preventing the entry of foreign pollen. For crossing, pollen are collected at this stage.

d. **Fully open flower.** The anthers become shrivelled, while the standard and wing petals are fully expanded. Fertilization takes place 24 h after pollination.

e. **Fading flower.** This is the postfertilization stage during which the ovary begins to elongate.

Chickpea being a highly self-pollinated crop, selfing is not required.

Anthesis

Anther dehiscence takes place inside the bud one day before the opening of the flower. When pollen are first liberated, the stigma is still above and quite free from the base of the anthers. The filament gradually elongates to carry the anthers above the stigma. This process is completed before the flower opens, thus facilitating self-pollination. Anthesis in chickpea is throughout the day (R.P.S. Pundir, ICRISAT, personal communication 1993).

Pod and Seed Development

Pod formation begins 5-6 days after fertilization. The pod is typically inflated, ending in a mucro and sometimes looking like a thorn. The number of pods plant^{-1} varies between 30 and 150, depending on the environmental conditions and the genotype. The pod wall is 0.3 mm thick with three layers-exocarp, mesocarp, and endocarp. The exocarp is hairy and glandular. The mesocarp has 6-8 layers of parenchyma. The endocarp consists of 3-4 cell layers with fibers in its outermost region and 5-6 layers of parenchyma (Cubero 1987).

Pod size ranges from 15 to 30 mm in length, 7-14 mm in thickness, and 2-15 mm in width. Depending on the basal and apical zones as well as the dorsal and ventral regions, pod shape varies from rhomboid, oblong to ovate.

The number of seeds pod^{-1} ranges from one to two, with the maximum being three. The seeds are ramhead or owl's-head shaped, and the surface may be smooth or wrinkled. The two cotyledons are separated by a groove in highly wrinkled seeds. The beak above the micropyle is produced by the tip of the radicle.

The shape of the cotyledons varies from semispherical to oviform. The length of the seed ranges from 4 to 12 mm and its width from 4 to 8 mm. The seed mass varies from 0.10 to 0.75 g seed^{-1}.

The seed color ranges from whitish (even chalky) and cream to deep black. Many other colors like red, orange, brown, green, and yellow may be found. The cotyledons are cream, green, or orange colored (Cubero 1987).

The procedures for recording morphological characteristics are discussed in Management Procedure (MP) 1 and for emasculation and crossing in MP 2.

Production Practices

Agroclimatic Conditions and Production Constraints

There are wide variations in the agroclimatic conditions under which chickpea is grown around the world. It is grown between 20°N and 40°N in the northern hemisphere. It is also cultivated on a small scale between 10°N and 20°N in India and Ethiopia at relatively higher elevations. These environments differ in photoperiod, temperature, and precipitation. Due to the variation in longitude, the time of sowing also varies from one region to another. Smithson et al. (1985) classified chickpea-growing areas into four major geographical regions.

a. Indian subcontinent
b. West Asia, North Africa, and Southern Europe
c. Ethiopia and East Africa
d. The Americas and Australia

Summerfield et al. (1990) listed the major agroclimatic constraints to production and productivity of chickpea (Table 2).

Table 2. Major agroclimatic constraints in production and productivity of chickpea.

Geographical region and soil group	Constraints		
	Germination/ seedling stage	Vegetative stage	Reproductive and maturation stage
South and Southeast Asia			
Vertisols	Hot and/or dry seedbeds	Supraoptimal temperatures (>30°C) and/or drought	Supraoptimal temperatures (exacerbated by cracking of soil)
Entisols	Hot and/or dry and/or saline seedbeds	Drought; soil salinity	Drought; soil salinity; frost damage
Asia and Mediterranean (winter rainfall areas)			
Mollisols and Vertisols	Cold and/or wet seedbeds; poor radiation	Cold temperature with or without frost damage	Drought; poor radiation; frost damage

Soil

Chickpea is grown on different types of soils ranging from sandy (dunes in the Thal' of Pakistan) to sandy loams (northern India) to deep black cotton soils (central India, West Asia, and the

Ethiopian highlands). It is also cultivated on calciferous soils with a subsoil layer of $CaCO_3$ in West Asia. The best soils for chickpea growth are deep loams or silty clay loams devoid of soluble salts (Moolani and Chandra 1970). Such soils retain up to 200 mm moisture in the soil profile up to a depth of 1 m (Saxena 1987). The maximum nutrient availability from the soil is at a pH range of 5.7 to 7.2 (Mahler et al. 1988). Chickpea requires good soil aeration. Therefore, heavy soils require care in seedbed preparation. In such soils a rough seedbed is useful as it is not prone to surface compaction due to winter rains which may hinder seedling emergence (Kay 1979).

Chickpea is highly sensitive to salinity and sodicity in the soil (Chandra 1980). Salinity has an adverse effect on dry-matter production and uptake of phosphorus, zinc, and iron (Dravid and Goswami 1987). Increase in salinity (chloride or sulfate) leads to a decrease in nodule weight, leghaemoglobin content, number and weight of pods plant^{-1}, 100-seed mass, and seed and biological yield. Salinity also restricts the outward movement of fixed nitrogen from the nodules, retards the translocation of nitrogen to the seeds, and increases its accumulation in the leaves and pod walls (Ram et al. 1989).

Cropping Systems

Chickpea cropping systems and production practices vary from region to region and also within a region.

The Indian subcontinent

In the alluvial soils of the Indo-Gangetic plain, chickpea follows rainy-season crops such as pearl millet, sorghum, maize, sesame, and early paddy in double-cropping systems. In sandy soils in northern India (the states of Punjab, Haryana, and Rajasthan) and the 'Thai' areas of Pakistan, it is grown either after pearl millet or after fallow when monsoon rains are insufficient. In central and peninsular India, chickpea is also grown in rotation with sugarcane and maize.

Chickpea is mainly grown as a mixed crop with oilseeds such as rape-seed, mustard, taramira (*Eruca sativa* Mill.), and linseed. It is also grown as a mixed crop with barley and lentil in northern India (Saxena 1987).

Mixed cropping of chickpea with wheat has been found to be quite remunerative. Asaduzzamam et al. (1989) reported that 50:50 chickpea-wheat mixed cropping gave the highest land-equivalent ratio. Sharma et al. (1987) also reported a high net return from wheat-chickpea mixed cropping at a ratio of 5:1. Singh and Yadav (1990) recorded higher yield and net return from wheat intercropping with chickpea than with sunflower, lentil, linseed, or peas. Quayyum et al. (1987) reported a high yield of maize and chickpea when maize was intercropped at a row spacing of 75 cm with two rows of chickpea. This combination yielded 5.5 t ha^{-1} of maize. Singh (1989) reported that double- cropping of short-duration rice followed by chickpea was better than a single long- or short-duration rice crop with full recommended fertilizer application. Sharma (1987) also reported high net returns from a rotation of transplanted rice and chickpea.

Intercropping of postrainy-season maize with chickpea (at 75 cm x 25 cm) at a 1:2 ratio gave 22% higher yield than sole maize (Quayyum et al. 1987). Sowing chickpea + 10% maize gave a higher return and cost-benefit ratio at Mymensingh in Bangladesh (Khaleque et al. 1990). Intercropping maize with chickpea gave a higher yield than sequential cropping of maize with wheat and maize with safflower in Karnataka, India (Setty et al. 1990).

Gupta and Meena (1989) reported that intercropping chickpea with safflower (3:1 ratio) with two irrigations gave the maximum yield in Udaipur, Rajasthan, India. Autkar et al. (1991) reported higher net return from a chickpea/safflower intercrop (8:1 row ratio) than chickpea/wheat, cowpea/mustard, and chickpea/ linseed in Maharashtra, India. In Ludhiana, India, an intercrop of mustard and chickpea when sown at a 1:1 ratio in the north-south direction, gave the highest yield (Dhingra et al. 1990).

At Ishurdi in Bangladesh, chickpea (30 kg ha^{-1} seed) intercropped with linseed (5 kg ha^{-1} seed) gave the highest net return and cost-benefit ratio (Islam 1989).

West Asia, North Africa, and Southern Europe

In this region, mainly *kabuli* chickpea is cultivated, the *desi* type being limited to a small area in Iran and the Nile Valley. The choice of cropping system depends on winter rainfall. In areas where the rainfall is more than 400 mm, chickpea is grown with cereals such as wheat and barley and also with melons, sesame, and forage crops. In the drier regions, a chickpea-fallow-winter cereal crop rotation is followed. In the Nile Valley, where the crop is sown after the rains when soil moisture is receding, chickpea is rotated with cereals, faba bean, and berseem. The irrigated crop is generally rotated with sorghum and maize (Saxena 1987).

Ethiopia and the East African Highlands

These areas are at elevations ranging from 1400 m to 2300 m. The soils here are clayey, with neutral to alkaline pH. Mostly *desi* chickpea is cultivated here in rotation with barley and wheat on conserved soil moisture at the end of the rainy season. In high-rainfall areas and in light soils, chickpea is being replaced with faba bean. Chickpea is grown as a sole crop or as a mixed crop with safflower and sorghum in Ethiopia and with maize in Kenya (Smithson et al. 1985).

America and Australia

In South and Central America, chickpea is grown in rotation with maize, soybean, sesame, wheat, or one or more years of pasture (Smithson et al. 1985). In USA the main production areas are in California, Washington, and Idaho under the *kabuli* type. In these places, the crop was introduced as an alternative to cereals in marginal rainfall areas. In the dry areas of eastern Washington and northern Idaho, it is rotated with wheat, barley, peas, and lentils (Kaiser and Hannan 1985).

In Australia, large-seeded *kabuli* chickpea is cultivated in rotation with wheat in the postrainy season under irrigation to increase the use of currently under-utilized irrigable land (Bennett and McNeil 1985).

Land Preparation

Land preparation for sowing chickpea is based on the soil type and cropping system. In the case of a heavy soil, a rough seedbed is prepared to avoid packing of the cloddy surface due to winter rains and to facilitate soil aeration and easy seedling emergence (Kay 1979; Arakeri et al. 1959).

When chickpea is cultivated as a mixed crop with linseed or mustard, the land is prepared to a fine tilth. It is necessary to deep-plow the field at the beginning of the rainy season. This opens the soil deep and ensures efficient moisture conservation. Deep plowing also reduces wilting of chickpea that tends to develop due to the presence of hardpans in the root zone (Moolani and Chandra 1970).

In India, chickpea is grown in heavy soils after rainy-season fallow. To conserve moisture, the soil is cultivated with an animal-drawn blade harrow (*bakhar*) attached to a heavy wooden log. This operation helps in weed control and seedbed compaction. In light soils, frequent shallow cultivation with a country plow is done late in the evening. This exposes a larger soil surface area to capture the dew in the night, and sowing is done the following morning. Such a practice conserves moisture and helps in weed control (Saxena 1987).

In West Asia and North Africa, land preparation is generally done after the rains cease. An additional cultivation *may* be done during the rainy season with a duck-foot cultivator which does not turn the soil completely to control winter weeds. This tillage leaves the soil surface with ridges and furrows for sowing. The use of duck-foot cultivators and disc harrows are common for land preparation (Saxena 1987).

Seed and Sowing

Use of good-quality seed in optimum quantity, proper seed treatment, and sowing ensure good germination, optimum plant stand, and high yield. The seed requirement depends on the seed mass, the germination percentage of the seed-lot, and plant population ha^{-1} (MP 5).

Temperature and moisture requirement

A viable chickpea seed with an initial moisture content of 10% may germinate when it has imbibed sufficient water to reach a moisture level of more than 80% (Saxena, N.P. 1984). Faster germination occurs at a temperature range of 31.8°C to 33°C (Covell et al. 1986). In a controlled environment, chickpea can germinate over a wider range (10°C to 45°C) of temperature (Roberts et al. 1980).

Seed treatment

To protect the crop from seedling diseases, it is recommended to treat seeds of *kabuli* cultivars with captan (Orthocide® 50 W) at 1.0 g kg^{-1} seed (Kaiser and Hannan 1985). The *desi* types can be treated with carbendazim (Bavistin®) at 1.5 g kg^{-1} seed (Thomas and Vyas 1984). Chickpea seed treated with a combination of quintozene and thiram, each at 1.5 g kg^{-1} seed, improved germination and seed yield without any adverse effect on nodulation (Bhattacharya and Sengupta 1984).

Sowing method and seeding depth

In India, West Asia, and North Africa, farmers use traditional plows with an attached V-shaped funnel (pora) for sowing. This implement places the seed at a depth of 10-12 cm in sandy and loam soils. The seeds are drilled into the furrows with a 5-7 cm soil layer over them. In West Asia, chickpea is sown after the cessation of rains. The seeds are dropped at a depth of 10-15 cm by a person sitting on a duck-foot cultivator drawn by a tractor. The duck-foot hoes are attached to the bar with a spacing of 45 cm between the hoes (Saxena 1987).

In high-rainfall areas, chickpea seeds are broadcast evenly on a flat seedbed and then covered with a duck-foot cultivator. In another method of sowing, the field is first plowed with a duck-foot cultivator and then the broadcast seeds are covered by another pass of the duck-foot cultivator (Saxena 1987). In all these cases the seeds are placed at a depth ranging from a few centimeters to as deep as 10-15 cm. Increase in seeding depth decreases the yield in *kabuli* cultivars while in *desi* cultivars the highest yield was obtained when the seed was sown at a depth of 12 cm (Haqqani et al. 1987).

Sowing with seed drills is not common in India and West Asia. However, in USA, southern Europe, and Australia, seeding is mechanized. Except some problems with bold-seeded varieties and ungraded seed, use of a seed drill allows a better control of seeding depth, row distance, and intrarow spacing. It also facilitates interrow cultivation for mechanical weed control (Saxena 1987).

Irrigated chickpea is also sown on ridges or broadbeds. The ridges are either freshly made or left over from the previous season. The seeds are dibbled on these ridges. In Australia and at ICRISAT Asia Center, India, sowing is done on 1.5 m wide broadbed-and-furrows (BBF) by opening 2 to 4 shallow furrows on each broadbed.

Time of Sowing

In India, mid October to mid November is the ideal period for sowing chickpea. Any deviation from this period causes a conspicuous reduction in yield (Dumbre and Deshmukh 1983; Saxena and Singh 1977). However, in rice-based cropping systems, chickpea sowing is delayed beyond the optimum date due to the late harvest of rice. Late sowing results in reduction in growth, preflowering and flowering periods, and has a considerable depressing effect on plant development. Consequently, yields are reduced (Eshel 1967).

In Maharashtra, India, October sowing gave higher yields than sowing in November or December (Deore et al. 1989). The late-sown crop produced less biomass, fewer seeds plant^{-1}, and had a low 100-seed mass. Similar observations were made by Arvadia and Patel (1988) in Gujarat. In Uttar Pradesh, early-October sowing gave a higher yield than sowing in late October, early November, and the third week of November (Yadav et al. 1989a).

In the central highlands of Ethiopia, the optimum sowing date is between early August and early September. Sowing earlier than August results in poor emergence and sparse plant stand due to excessive rains, while late sowing reduces the crop duration which affects crop growth and development adversely (Bezuneh 1975; Bejiga and Tullu 1982).

In West Asia and Chile, the third week of August is the best sowing time (Penaloza 1984). In Washington and northern Idaho, USA, the appropriate time of sowing for *desi* and *kabuli* chickpea is mid April to mid May (Kaiser and Hannan 1985). In Australia, the date of sowing ranges from early May to late July for the *kabuli type.* Early-May sowing gave the highest yield in the Ord River irrigation area (Bennett and McNeil 1985). Late sowing resulted in reduced yield and poor seed quality.

The optimum date of sowing for different regions is given in Table 3.

Table 3. Optimum time for sowing chickpea In different parts of the world.

Country	Time of sowing	Reference
Afghanistan	November-December	Habibi 1990
Argentina	June-July	van der Maesen 1972
Australia	May--July	Bennett and McNeil 1985
Bangladesh	November-December	Rashid Shah and Yousuf 1987
Bulgaria/Chile	3rd week of August	Penaloza 1984
Egypt	November	Saxena et al. 1995
Ethiopia	Late August—early September	Bejiga and Tullu 1982 Bejiga 1990
India	Mid October-mid November Mid September-November	Dumbre and Deshmukh 1983 Saxena and Singh 1977 van der Maesen 1972
Iran	March-April	Sadri and Kahrobaian 1990
Iraq	November-December	Abbas 1990
Italy	November-December	Calcagno et al. 1988
Lebanon	Spring: February-March Winter: November-December	Saxena et al. 1995
Mexico	October-November	Saxena et al. 1995
Pakistan	Late October-mid November	Saxena et al. 1995
Spain	Spring: March-April Winter: November-December	Saxena et al. 1995 Saxena et al. 1995
Sudan	November-December	Mohamed 1990
Syria	Winter: Late November- December Spring: March	Saxena et al. 1995 Saxena et al. 1995
Tunisia	Spring: March-April Winter: November-December	Saxena et al. 1995 Saxena et al. 1995
Turkey	December-February	Sarkar and Yilmaz 1990
USA	Mid April-early May	Kaiser and Hannan 1985
USSR	May	Efimov 1991

Plant Density

Chickpea is grown at a plant density of 33 plants m^{-2} in a flat- or broadbed-and-furrow system at ICRISAT Asia Center, Patancheru, India. The plant density ranges from 25 to 30 plants m^{-2} in a ridge-and-furrow system. Tall and erect cultivars gave high seed yield at a higher plant density (25 to 30 plants m^{-2}) due to their apical pods (Calcagno et al. 1988).

Higher plant densities have been reported to be more appropriate for late sowing. At Kanpur, India, chickpea sown in early December at densities of 33 plants m^{-2} and 44 plants m^{-2} gave yields of 1.96 t ha^{-1} and 2.11 t ha^{-1} respectively (Ali 1988). Shakhawat and Sharma (1986) reported that in late-sown conditions, increase in seed rate (from 70 kg ha^{-1} to 140 kg ha^{-1}), reduction in row spacing (from 30 cm to 22.5 cm), and sowing in bidirectional rows gave a higher yield.

Mane and Jadhav (1991) reported high seed yield and highest N and P uptake at a plant density of 45 plants m^{-2}, though P uptake was highest at 30 plants m^{-2} in Maharashtra, India. Similarly, Thakur and Jadhav (1990) recorded higher yield at 45 plants m^{-2} than at 30 plants m^{-2} in Maharashtra. Yadav et al. (1989a) reported higher yield of *kabuli* chickpea at 33 plants m^{-2} than at 17 and 22 plants m^{-2}. Sarawgi and Singh (1989) reported higher chickpea yield at a density of 50 plants m^{-2} than at 30 plants m^{-2} at Pantnagar, India.

Murray and Auld (1987) reported that a row spacing of 15 cm and plant spacing of 6 plants m^{-1} was optimum for high yields in Moscow. Further, sowing of 14% small-sized seed reduced the sowing cost by 30% without causing a reduction in seed yield and seed weight over the largest-sized seed in the seed- lot.

The optimum plant population depends upon the genotype and the environmental conditions under which the crop is grown. In India, a population of 33 plants m^{-2} appears to be the best (Saxena 1980; Singh 1983). In Iran, yield increase was recorded with an increase in population up to 50 plants m^{-2} under irrigated conditions and up to 25 plants m^{-2} in nonirrigated spring-sown chickpea (Anonymous 1976). A decrease in row spacing from 60 cm to 30 cm increased the yield of winter chickpea by 52% in western Jordan (Kostrinski 1974). A similar response was observed in Cyprus (Photiades 1984). In Syria, when the population density was raised from 18 to 28 plants m^{-2} in winter, there was a significant increase in yield, but the same response was not observed in the spring-sown crop (Saxena 1980). Compact, upright-growing plants responded better to increased plant density than the spreading type (Singh 1981). In Bangladesh, a plant density of 30 plants m^{-2} at a seed rate of 60 kg ha^{-1} was found to be appropriate for good growth and yield (Paramanik et al. 1990).

Mane and Jadhav (1991) reported higher nodulation and dry-matter production with 30 plants m^{-2} than with 45 and 60 plants m^{-2}, and seed yield was highest at 45 plants m^{-2}. Plant density and inter- and intrarow spacing are location- specific and depend on genotype, growth environment, and inputs. Ali (1989a) compared the results of plant density experiments conducted at Badnapur, Maharashtra, involving two varieties, one *desi* (BDN 9) and another *kabuli* (L 550). It was concluded that a spacing of 30 cm x 10 cm for the *desi* type and 45 cm x 15 cm for the *kabuli type* was optimum, giving a yield of 2848 kg ha^{-1} and 1592 kg ha^{-1} respectively. Sowing on a flatbed with interrow spacing of 30 cm and intrarow spacing of 10 cm was recommended (ICRISAT 1987).

The procedure for calculating the seed requirement for different population densities is discussed in MP 3.

Nutrient Requirement

Being a legume, chickpea obtains its nitrogen through nitrogen fixation. It requires optimum amounts of phosphorus, potash, sulfur, and other nutrients. The response to nutrient application in chickpea depends on the nutrient status of the soil, agroclimatic conditions, and the genotype. Both organic and inorganic sources of nutrients and *Rhizobium* inoculation have been found to be useful for chickpea growth and yield.

The nutrient-deficiency symptoms for chickpea are presented in MP 4. The response to nutrients is discussed here.

Nitrogen (N)

An application of 15-25 kg N ha^{-1} has been found to be optimum for stimulating growth and yield of chickpea in sandy and loam soils (Saxena and Yadav 1975). However, when an active symbiotic nitrogen-fixing system was present, there was no response to nitrogen application up to 100 kg N ha^{-1} (Saxena and Sheldrake 1980a). In the alluvial soils of India, an application of 30-40 kg N ha^{-1} was found to be profitable under rainfed cultivation (Rajendran et al. 1982). Application of 20 kg N ha^{1} increased chickpea yield in sandy loam soils. A high yield was obtained with 20 kg N ha^{-1} and *Rhizobium* inoculation in Gujarat, India (Patel and Patel 1991).

Increase in yield was reported with nitrogen application as basal dose and at postflowering stage. Nitrogen application during the postflowering stage enhanced nitrate reductase activity and yield (Sekhon et al. 1988). Saxena and Yadav (1975) indicated that N uptake by chickpea may range from 60 to 200 kg N ha^{-1}. Foliar application of 2% urea increased yield at some locations (Ali 1989b).

Phosphorus (P)

The response to phosphate application depends on the available soil P and other edaphic factors (Saxena and Yadav 1975). On Vertisols which are low in P content, there was no response to broadcast or deep-placed P application (Saxena and Sheldrake 1980a). On terrarosa soils in Syria, with an available soil P level of less than 2.5 mg kg^{-1}, application of 22 kg P ha^{-1} as triple superphosphate has been quite effective (Saxena, M.C. 1984). On alluvial soils in India with low available soil P, a 78% increase was observed in seed yield with an application of 32 kg P ha^{-1} under rainfed conditions (Singh et al. 1981).

The effect of phosphorus application was more pronounced when it was in conjunction with starter N, *Rhizobium* (Pal 1986), and irrigation (Daftardar et al. 1988). Phosphorus application gave a yield increase of 30% under nonirrigated conditions and about 40% under supplemental irrigation. Supplemental irrigation increased consumptive water use as well as water-use efficiency (Prabhakar and Saraf 1989). Application of 17.48 kg P ha^{-1} as single superphosphate with two irrigations gave maximum seed yield. Phosphorus application significantly increased dry-matter production and resulted in greater diversion of dry matter to pods. Further, more dry matter was produced with one or two irrigations at 0.4 IW: CPE, indicating greater dry-matter production with irrigation during the vegetative phase of chickpea (Prabhakar and Saraf 1991). Utilization of P was better when it was applied as a basal dose than as topdressing or foliar application (Singh and Kamath 1989).

Saxena et al. (1988) reported no response to P application in Vertisols where the available soil P level was 2 to 5 mg kg^{-1} at ICRISAT Asia Center, India. The P concentration in shoots of 30-day-old plants in the absence of P fertilizer was greater than the critical (0.6%) level reported for chickpea growth. This declined rapidly with the advancement of growth and, at maturity, it was only 0.2%. In Vertisols, chickpea produced 400 kg of shoot mass and 20Q kg of seed yield for each kg of P uptake.

Varughese and Pathak (1987) reported that application of diammonium phosphate at 50 kg ha^{-1} as basal dose and 50 kg ha^{-1} split equally at branching and flowering stages produced the highest chickpea yield (2470 kg ha^{-1}) and a cost:benefit ratio of 1:2.69. Idri et al. (1989) reported a 59% yield increase at 26 kg P ha^{-1} and 54% at 35 kg P ha^{-1}.

Borgohain and Agrawal (1986) reported that the source of P (single super- phosphate, triple superphosphate, or phospho-composite) had no significant effect on chickpea yield. The highest yield was at 35 kg P ha^{-1} with two irrigations at Hisar, India. Tomar et al. (1987) reported that superphosphate was a better source of P than monoammonium phosphate.

In a comparison of P application methods under irrigation, mixing in soil (15 cm depth) proved superior to banding at 5 cm depth (Arihara and Ae 1988). Pala and Matar (1988) reported that in Syria band application of P did not differ significantly from broadcasting and incorporating in plow layer before sowing. Arihara et al. (1991) reported that incorporating P in the topsoil layer was more effe'ctive than its placement in shallow bands but was less effective compared to placement in deep bands at 15 cm depth, under rainfed conditions. This may be due to the higher and stabler soil moisture levels at 15 cm depth.

Potassium (K)

Information on the response of chickpea to potassium application is limited. There was no response or a negative response due to the high levels of available K in chickpea-growing soils (Saxena and Yadav 1975; Hamidullah et al. 1989). In India and Pakistan, application of 17 to 50 kg K ha^{-1} increased chickpea yield from 18 to 20% (Thakur et al. 1989).

Balanced fertilizer application

Singh and Sharma (1983) suggested a procedure for calculating the specific requirement of N,P, and K for a targeted seed yield of chickpea. This was 4.48 kg N, 0.34 kg P,.and 3.15 kg K for 100 kg of chickpea seed yield. Kar et al. (1989) reported the highest seed yield at 40 kg N + 35 kg P + 40 kg K ha^{-1} in acidic sandy loam soil in Orissa, India. Khokar and Warsi (1987) reported the highest yield (2600 kg ha^{-1}) at 18 kg N + 20 kg P + 40 kg K + 25 kg $ZnSO_4$ ha^{-1} at Faizabad, Uttar Pradesh, India.

Tomar et al. (1987) reviewed the work done on fertilizer management in chickpea and reported significant economic returns from N and P application. In low- fertility soil, P application was more profitable. A balanced.application of N and P resulted in higher yields and net returns than the application of either nutrient alone. From this review, they concluded that balanced application of fertilizer should be based on a soil test and the targeted yield.

Calcium (Ca)

In sodic soils, application of 300-500 kg ha^{-1} gypsum ($CaSO_4$) was effective in increasing the rate of germination, nodulation, and seed yield (Yadav et al. 1989b).

Sulfur (S)

Application of 10 kg elemental sulfur in a sandy loam soil increased the nitrogen and phosphorus uptake and the yield (Gupta and Singh 1983). Singh and Ram (1990) also reported that sulfur application in the range of 40-80 kg ha^{-1} increased the yield and seed protein content. In saline-alkaline soils, application of grounded pyrites (FeS_2) allowed greater symbiotic nitrogen fixation and resulted in higher yield (Rai and Prasad 1983). Tiwari and Pathak (1988) also reported an increase in chickpea yield in alkaline soils with the application of 200-400 kg ha^{-1} pyrites.

Zinc (Zn)

Zinc deficiency generally occurs in soils with a high pH and in areas under chickpea-rice cropping system. Basal application of zinc sulfate (10—25 kg ha^{-1}) resulted in a positive response in terms of seed yield (Dhingra et al. 1978). Foliar application of 0.5% zinc sulfate (ZnS04) mixed with 0.25% lime was found to be effective in correcting zinc deficiency (Saxena and Singh 1977). Thakur et al. (1989) reported a 16% increase in seed yield with an application of 25 kg $ZnSO_4$ along with N, P, and K. A basal application of 40 kg zinc sulfate ha^{-1} every alternate year was also recommended or one spray of zinc sulfate solution at the rate of 10 kg ha^{-1} in 200-300 L of water added to 200-250 mL of liquid soap added as sticker to correct zinc deficiency in chickpea (ICRISAT 1987).

Iron (Fe)

In calcareous soils with a high pH, chlorosis is caused by the nonavailability of iron due to waterlogging. This deficiency can be corrected by a foliar spray of 0.5% W/W $FeSO_4$. Such an application increased the yield by up to 50% in genotypes that were inefficient in iron utilization, but found no response in cultivars that were efficient (Saxena and Sheldrake 1980b). In calcareous soil, a spray of 2% $FeSO_4$ 30 days after sowing increased yield (Perur and Mithyantha 1985).

Manganese (Mn)

Manganese deficiency in chickpea occurs when Mn content is 10 mg kg^{-1} or lower in the leaves of nine-week-old plants. Such a crop needs to be sprayed with Mn (Agrawal and Sharma 1979). In dry loam soils with 16.3 mg kg^{-1} Mn, there was an improvement in nodulation and dry-matter yield with increasing levels of $MnSO_4$ from 0 to 20 kg ha^{-1}. The optimum rate may range from 10 to 25 kg $MnSO_4 ha^{-1}$ as soil application and 1.0 to 2.5 kg ha' as foliar spray. In general, the foliar spray was superior (Kalbhor et al. 1988).

Boron (B)

In general, soil application of 1-2.5 kg B ha^{-1} or foliar application of 0.25 kg B ha^{-1} in the form of borax is adequate to mitigate boron deficiency in chickpea (Ahlawat 1990).

Copper (Cu)

Copper availability is low in calcareous and acidic soils as well as in saline and sodic soils. Coarse-textured soils are more deficient in copper than fine- textured soils. In such soils, 5-10 kg $CuSO_4$ ha^{-1} as soil application or 0.5-1.0 kg $CuSO_4$ ha^{-1} as foliar spray is recommended (Ahlawat 1990).

Molybdenum (Mo)

Soils which have a high clay content and are lateritic in nature generally have low available molybdenum. Availability of molybdenum is high in saline, alkaline, and calcareous soils. Application of 1.5 kg sodium molybdate ha' with phosphorus and *Rhizobium* inoculation led to a marked increase in yield (Pal 1986; Ahlawat 1990).

Farmyard Manure

The effect of farmyard manure (FYM) application on yield and growth was negligible in chickpea except an increase in the number of secondary branches (Patel and Patel 1991).

Rhizobium Inoculation

Chickpea is generally inoculated with *Bradyrhizobium* sp cicer. The effect of *Rhizobium* inoculation on chickpea yield depends on the native rhizobial status. Fields in which well-nodulated chickpea was grown previously do not require *Rhizobium* inoculation. However, where chickpea is being grown after paddy or chickpea is being introduced for the first time, *Rhizobium* inoculation is necessary (ICRISAT 1987). A yield increase of 12% was recorded with *Rhizobium* inoculation alone. *Rhizobium* inoculation along with the recommended fertilizer application increased yield by 40% in the Sabour and Bhagalpur areas of Bihar, India (Singh et al. 1989a). In alluvial soils (Udic Ustochrepts), inoculation of composite strains of *Rhizobium* with phosphorus and molybdenum gave a better yield than inoculation of a single strain of *Rhizobium* (Tiwari et al. 1989). When *Rhizobium, Bacillus polymyxa,* and *Glomus fasciculatum* were applied separately in pot experiments, inoculation with *Rhizobium* alone markedly increased N uptake by the plant. In the other treatment in which all the three test organisms were applied, it resulted in significantly higher dry-matter production and phosphate uptake as compared with single or double inoculation of the test organisms. The trial also suggested that *Glomus fasciculatum* and phosphobacteria can greatly assist symbiotic N fixation as well as phosphate uptake in chickpea, particularly when the crop is grown in a soil containing soluble phosphates.

Singh and Tilak (1989) reported that chickpea already inoculated with *Rhizobium leguminosarum,* when inoculated with *Glomus versiformes* also under field conditions, showed a 12% increase in shoot dry weight and 25% in seed yield. When P was applied in addition to inoculation, the yield increase was 33% and 60% for these strains respectively.

Pala and Mazid (1992) summarized the results of 30 on-farm trials conducted over four seasons in northwestern Syria. They concluded that the effects of *Rhizobium* inoculations on chickpea were very small and inconsistent. *Rhizobium* inoculation procedures are given in MP 5.

Application of *Azolla*

Presowing application of *Azolla pinnata* at 5 t ha^{-1} with 12.5 kg N ha^{-1} gave an average seed yield of 1.56 t ha^{-1} compared to 1.4 t ha^{-1} with 25 kg N ha^{-1}, 1.34 t ha^{-1} with 5 t FYM ha^{-1}, and 1.13 t ha^{-1} without *Azolla* and fertilizer in Maharashtra, India (Veer and Patil 1987).

Weed Management

Many species of weeds have been reported to infest chickpea fields (Table 4). The first four to six weeks of crop growth are most crucial for weed competition (Saxena et al. 1976; Ahlawat et al. 1981). Tripathi (1967) reported 40% reduction in the dry mass of chickpea pods when weeds were allowed to compete with the crop. Sadaphal (1988) reported that the loss of chickpea yield due to weeds was as high as 50%. Ali (1989b) reported a yield loss of 95% in the control (unweeded) plot compared to the weed-free chickpea plot. Pala and Mazid (1992) examined the results of 30 on-farm trials conducted over three seasons in northwestern Syria and concluded that weed control with terbutryn (2.0 kg ha^{-1}) + pronzamide (0.5 kg ha^{1}) increased seed yield significantly over nonweeded plots, but was less effective than hand weeding.

Table 4. Common weeds of chickpea in different parts of the world.

Country (region)	Weeds (reference/s)
Argentina	*Croton labathus* and *Spitanthes urens* (Diaz 1977).
Australia (New South Wales)	*Sisymbrium* sp (Department of Agriculture, New South Wales 1977).
Bulgaria	*Sinapsis arvensis, Chenopodium album, Amaranthus retroflexus, Veronica hederifolia,* and *Polygonum aviculare* (Kovachev et al. 1968).
India	*Chenopodium album, Melilotus indica, Lathyrus aphaca, Medicago denticulata, Trigonella polycerata, Polygonum plebijum, Asphodelus tenuifolius, Euphorbia dracunculoides, Anagallis arvensis,* and *Trichodesma indicum* (Gupta et al. 1977; Kolar et al. 1982; Saxena et al. 1976; Tripathi 1967, 1968; Yadava et al. 1983). *Cuscuta hyaline** (Vyas and Joshi 1975).
Lebanon (Terbol)	*Sinapis arvensis, Raphanus raphanistrum, Veronica arvensis, Lamium amplexicaule, Galium* sp, *Avena sterilis,* and *Phalaris brachystachys* (ICARDA 1979).
Mexico (Sonora)	*Convolvulus arvensis, Chenopodium* sp, *Melilotus indica, Phalaris minor,* and *Polygonum* spp (Bernal 1981).
Morocco	*Avena sterilis* and *Phalaris* spp (Geigy 1969).
Palestine	*Molucella laeviz, Chrozophora tinctoria, Avena sterilis,* and *Phalaris* spp (Eshel et al. 1979). *Cuscuta compestris* (Graf et al. 1982).
Syria (Tel Hadya)	*Sinapsis arvensis, Geranium tuberosum, Scadix* sp, *Carthamus syriacus,* and *Phalaris brachystachys* (ICARDA 1979).
Syria (Jindiress)	*Sinapsis arvensis, Euphorbia* sp, *Scorpiorus subvilosus,* and *Phalaris brachystachys* (ICARDA 1979).
United States ot America (Idaho)	*Thalaspi arvense, Anthenis cotula,* and *Chenopodium album* (Auld and Lee 1981).

* Parasitic weed.

Ali (1989b) reported that one hand weeding at 25-30 days after sowing was adequate to control weeds in chickpea. Weed-management procedures are discussed in MP 6.

Irrigation

Chickpea is better adapted at low water supply. The consumptive water use (E_T) of chickpea depends on soil moisture and yield level. It ranges from 110 to 280 mm for a seed yield of between 900 and 3000 kg ha^{-1} (Singh and Bhushan 1979). Chickpea needs 15% soil moisture by volume in the root zone, extending as deep as 50 cm in sandy loam soil. This amount is critical during seed development (Baldev 1988). Chickpea meets its water requirement from conserved moisture in deep soils (more than 150 cm depth) (Saxena, N.P. 1984). Therefore, the extractable moisture in the soil profile can be increased by employing management practices that encourage root growth or by using genotypes with a deeper and more prolific root system (Saxena 1987). Another way to meet the water requirement in deep soils is by using early-maturing varieties.

Chickpea is more responsive to irrigation in high water evaporation areas such as peninsular India. Where evaporation is low, frequent irrigation tends to cause excessive growth, lodging, and lower yields (Saxena, N.P. 1984). The late-flowering and pod-setting stages appear to be the most sensitive to drought stress (Palled et al. 1985). However, care must be taken to avoid water stagnation as chickpea is very sensitive to poor soil aeration (Saxena 1987).

The response to drought stress depends on the genotype, climate, soil condition, and the growth stage at which stress is experienced. The three stages of plant growth are sowing to preflowering, flowering, and pod development and maturation. Drought stress should be minimum during flowering and pod development for good yield in chickpea (Farah et al. 1988). Duron Noriega (1986) determined the level of soil humidity (0, 10, 20, and 30 percent) before and after flowering in some chickpea varieties. No significant difference was recorded in seed size, seed yield, haulm production, and quality of chickpea due to variation in humidity. However, at high relative humidity, production of seed and straw increased but seed size decreased.

Saxena et al. (1990) reported that with one or two irrigations, the yield of *kabuli* chickpea increased by 73% in winter and 143% in spring compared to a crop grown under 373 mm rainfall at Tel Hadya, Syria. They concluded that irrigation can increase the productivity and yield stability of chickpea in northern Syria, depending on the rainfall and its distribution during the crop growth period. During the winter season, when the rains fail, a supplemental irrigation improved yield by 12.5% to 46% in New Delhi, India (Prabhakar and Saraf 1989).

Under the *terai* conditions of Pantnagar, India, irrigation after 90 days of sowing was found to be most beneficial to chickpea (Naresh et al. 1985). Roy et al. (1988) reported that one irrigation after 45-50 days of sowing or at pod initiation was beneficial for high yield of late-sown chickpea in Bihar, India.

Parihar (1990) reported that water-use efficiency (WUE) decreased with increase in irrigation frequency. Maity and Jana (1987) reported that one irrigation at the preflowering stage was optimum for high seed yield and high water-use efficiency in Kalyani, West Bengal, India.

Prasad and Singh (1987) reported that maintenance of 75% available soil moisture before sowing gave a significantly higher yield than at 25% and 50% available soil moisture at Agra, India. High water-use efficiency was observed with 75% available soil moisture and 20 kg N + 26 kg P ha^{-1}. The upper soil layer (60 cm) contributed 38.71-44.35% of the total soil water used by the crop.

Under normal-sown conditions, chickpea meets its water requirement from soil moisture conserved from the monsoon season and winter precipitation. However, when winter precipitation fails, it responds well to one supplemental irrigation at early pod-filling stage (45 or 50 days after sowing). In heavy soils and under late-sown conditions, it is better to provide two irrigations, one at branching and another at the pod-initiation stage (Yadav 1991). Saxena (1980) recommended supplementary irrigation during the vegetative growth period of chickpea in light soils with a low water-holding capacity or during the latter period of vegetative growth and early pod-filling stages in heavy deep soils. Gaur and Choudhary (1993) concluded that chickpea production can be increased by applying two irrigations, at preflowering and pod-formation stages, in Rajasthan, India.

Biodegraded organic chemicals to conserve moisture

Water-absorbing polymers are useful when incorporated in the seed furrows as seed coating or as dust mulch. Their application at 8 kg ha^{-1} by incorporation in the field with 18 kg N ha^{-1} and 20 kg P ha^{-1} gave the highest yield over control and other methods of application (Singh et al. 1989b). A soil dressing of Jalshakti® at 7.5 kg ha ' with a presowing irrigation gave a higher yield compared to the control in Orissa (Barik et al. 1991). Gaur and Choudhary (1993) also reported that application of Jalshakti® at 6 kg ha^{-1} gave a 21.7% yield advantage over the control plot.

Effect of nipping

There is a general belief that nipping of foliage at an early stage induces more branching, restricts profuse growth, and leads to a higher yield. Patel et al. (1989) did not find any effect of nipping on crop yield when it was done at 20 and 40 days after sowing.

Harvesting

Paturda and Phirka (1990) reported that application of N and P at a high rate (35 + 70 kg ha^{-1}) delayed the harvest slightly. This practice increases the germination percentage of the harvested seed, and does not have any effect on the milling and cooking quality of the seed. The crop should be harvested when leaves start senescence and shedding. The plants are harvested at the base by manual labor, using a sickle or by using a combine harvester. After harvest, the crop is allowed to dry in the sun for a few days. Threshing is done either by beating the plants with sticks or with a thresher. Traditionally, farmers thresh their crop by trampling it with bullocks, camels, or horses. In this process, the dried crop is spread in a circle of about 15 m^2. The bullocks are allowed to walk on the plants in circles for an hour or more depending on the amount of material to be threshed. Continuous stirring of material at intervals of 15 to 20 min is required for uniform threshing. For easy threshing and to avoid damage to the seed, it is better to take out the seed from the threshing lot when about 60-70% seeds have separated from the straw.

MP 1. Recording the Morphological Characteristics of Chickpea

Days to emergence. Number of days from the date of sowing (at optimum moisture) to 80% seedling emergence.

Days to 50% flowering. Number of days from the date of sowing (irrigation) to the date on which at least 50% of the plants have at least one flower.

Plant density. It is important to know the number of plants contributing to the yield at harvest. Therefore, plants harvested from the net plot are counted and the population (in '000s) ha^{-1} is recorded.

Growth habit. The angles of primary branches are recorded in the sixth week after sowing on a 1-5 scale.

Score	Plant type	Description
1	Erect	0-15° from the vertical
2	Semi erect	15-25° from the vertical
3	Semi spreading	25-60° from the vertical
4	Spreading	60-80° from the vertical
5	Prostrate	Branches flat on the ground

Plant height (cm). Height is measured after flowering or at maturity from the base of the plant to the top of the main shoot. Average of 5-10 plants.

Primary branches (number). Basal primary branches emerge directly from the main shoot. Average of 10 plants.

Secondary branches (number). These are counted for 5-10 consecutive plants in the net plot.

Days to maturity. Number of days from the sowing date to the date on which 80% of the plants have mature pods.

Number of pods $plant^{-1}$. Pods of 5-10 plants selected randomly from the net plot are counted and the average number of pods $plant^{-1}$ calculated.

Pods $peduncle^{-1}$. Pods on 5-10 peduncles are counted from which the average number of pods $peduncle^{-1}$ is calculated.

Seeds pod^{-1}. Seeds from 10 pods are counted to compute the average number of seeds pod^{-1}.

Seed yield $plant^{-1}$ (g). Yield $plant^{-1}$ is recorded for use in biometrical or genetic studies in which individual plant data are required. The yield is recorded for each plant or as an average of 5-10 plants.

Biological yield (kg ha^{-1}). The mass of above-ground shoot with pods, stem, and foliage are weighed.

Yield (kg ha^{-1}). The harvested plants in the net plot (excluding the border rows) are threshed, dried, and cleaned to record the yield. The net plot yield is converted to kg ha^{-1} rounding it off to the nearest 10 kg. For example, a yield of 1986 kg ha^{-1} should be recorded as 1990 kg ha^{-1} and a yield of 1982 kg ha^{-1} as 1980 kg ha^{-1}.

Harvest index (%). It is the proportion of seed yield to biological yield.

$$\text{Harvest index} = \frac{\text{Seed yield (g)} \times 100}{\text{Biological yield (g)}}$$

100-seed mass (g). A random sample of 100 seeds is drawn from the dried bulk harvest (8% moisture) and weighed on a precision balance to record its mass to the nearest gram.

Seed shape. This is for identification of individual genotypes. The scoring is done as given below (Pundir et al. 1985).

Score	Seed shape
1	Angular, ram's head (mostly *desi* cultivars)
2	Owl's head shaped (mostly *kabuli* cultivars)
3	Pea-shaped, smooth, and round (can be either *desi* or *kabuli* type)

Seed color. The variation observed in chickpea seed color is: black; brown; light brown; dark brown; reddish brown; grayish brown; salmon brown; orange brown; gray (grayed green); brown beige; yellow; orange; yellow beige (orange-white); ivory white; green; light green; variegated; black-brown mosaic; brownish red; and light orange (Pundir et al. 1988). The seed color is recorded accordingly.

Testa texture. This is scored as:

Score	Testa texture
1	Rough
2	Smooth
3	Tuberculated

Scores for pest and disease reactions. Reaction to major pests like *Helicoverpa armigera* and diseases such as wilt, Ascochyta blight, stunt, and dry root rot are recorded on a 1-9 scale, under natural or artificially inoculated conditions. A general description is given here.

Score	Reaction
1	Highly resistant
3	Resistant
5	Moderately resistant
7	Susceptible
9	Highly susceptible

MP 2. Emasculation and Crossing in Chickpea

Material required. Forceps, alcohol to sterilize the forceps, colored nylon threads, lens, pencil, and record book.

Selection of buds for emasculation

Buds that are likely to be in anthesis after one or two days are selected for emasculation. In such a bud (hooded bud), the anthers are not yellow.

Method of emasculation

The bud to be emasculated should be held gently at the base with the thumb and fore finger. Snip off the frontal sepal. Push the keel petal downwards by slitting it with a fine-pointed forceps to expose the anthers.

Remove the anthers and count them, and also check with the help of a lens to ensure that no anther is left in the flower.

The pedicel, style, and stigma are fragile. Therefore, care must be taken not to damage these parts during emasculation. A colored cotton thread is tied loosely around the pedicel of the emasculated flower for identification. The emasculated flowers are usually not covered with a setting bag to prevent cross- pollination.

Pollination

Pollination is accomplished in the following ways:

1. Singh and Auckland (1975) recommended simultaneous emasculation and pollination. They also reported that at ICRISAT Asia Center, Patancheru, India, pollination can be done at any time between 0800 and 1700 h and this practice gives an almost similar pod-set. However, Pundir and Reddy (1984) found no difference in pod-setting and purity of crosses whether pollination was done simultaneously or a day after emasculation.

2. If a cross is to be made involving parents of contrasting flower color and other morphological characters, then pollination can be done without emasculation (Dahiya 1974).

The natural rate of pod-setting in chickpea lies between 18 and 59%. Singh and Auckland (1975) reported 24% pod-setting when artificial pollination was done on the same day as emasculation and 15% pod-setting when it was done one day after emasculation.

Low seed-setting in chickpea is mainly due to high humidity and cloudy weather. However, van der Maesen (1972) did not find pollination or fertilization to be affected by relative humidity per se. He suggested that suboptimum soil humidity affects seed-setting.

Pod and seed development

When crossing is successful, the pedicel remains fresh and pod formation starts within five or six days. Mature pods are harvested 60 days after pollination.

MP 3. Determination of Seed Rate for a Given Plant Density

The seed rate ha^{-1} depends on the recommended plant density, seed mass, and the germination percentage of the seed-lot. To ensure optimum plant stand, it may be desirable to add an additional 15-20% seed.

Example. Suppose the required plant population is 333 000 chickpea plants ha^{-1}, and the 100-seed mass is 15 g and the germination percentage of the seed-lot is 90%. From this information we can calculate the seed requirement ha^{-1} and for a plot of 15 m^2 (3 m x 5 m) with eight rows of 5 m length each spaced 0.375 m apart.

Calculations

a) To have 100 germinable seeds from the seed-lot with 90% germination, we need:

$$100 \times 100 \div 90 = 111 \text{ seeds}$$

So to obtain 100 seedlings, at least 111 seeds should be sown.

b) The seed required to establish a plant stand of 333 000 plants ha^{-1}

$$= 333\ 000 \times 111 \div 100 = 369\ 630 \text{ seeds ha'}$$

c) The mass of 369 630 seeds @ 15 g 100^{-1} seed

$$= (369\ 630 \times 15 \text{ g}) \div (1000 \text{ g kg}^{-1} \times 100) = 55.4 \text{ kg}$$

d) To sow additional 20% seed, the requirement of seeds

$$= 55.4 \text{ kg} \times 1.2 = 66.5 \text{ kg ha}^{1}$$

e) The seed required m^{-2} @ 66.5 kg ha^{-1}

$$= (66.5 \text{ kg ha}^{-1} \times 1000 \text{ g kg}^{-1}) \div (10\ 000 \text{ m}^2 \text{ ha}^{-1}) = 6.65 \text{ g m}^{-2}$$

f) The seed required for a 15 m^2 plot @ 6.65 g m^{-2}

$$= 6.65 \text{ g m}^{-2} \times 15 \text{ m}^2 = 99.8 \text{ g or } 100 \text{ g plot'}$$

g) The seed required row^{-1} (row area = 5 m x 0.375 m = 1.875 m^2)

$$= 6.65 \text{ g m}^{-2} \times 1.875 \text{ m}^2 \text{ row}^{-1} = 12.46 \text{ or } 12.5 \text{ g row}^{-1}$$

The seed rate for chickpea at different levels of population density, germination percentage, and 100-seed mass are presented in Table 5.

Table 5. Chickpea seed requirement[1] (kg ha^{-1}) for different levels of plant density, germination percentage, and 100-seed mass.

100-seed mass (g)	Plant density ha^{-1}								
	250 000 plants			333 000 plants			450 000 plants		
	Germination (%)			Germination (%)			Germination (%)		
	80	90	100	80	90	100	80	90	100
15	46.9	41.6	37.5	62.4	55.4	49.9	84.4	74.9	67.5
16	50.0	44.4	40.0	67.2	59.7	53.8	90.0	79.9	72.0
17	53.1	47.2	42.5	70.7	62.8	56.6	95.6	84.9	76.5
18	56.2	49.9	45.0	74.9	66.5	59.9	101.2	89.9	81.0
19	59.3	52.7	47.5	79.0	70.1	63.2	106.8	94.9	85.5
20	62.5	55.5	50.0	83.2	73.9	66.6	112.5	99.9	90.0
21	65.6	58.3	52.5	87.4	77.6	69.9	118.1	104.9	94.5
22	687	61.0	55.0	91.6	81.5	73.3	123.7	109.8	99.0
23	71.9	63.8	57.5	95.7	85.0	76.6	129.4	114.9	103.5
24	75.0	66.6	60.0	99.9	88.7	79.9	135.0	119.9	108.0
25	78.1	69.4	62.5	104.0	92.3	83.2	140.6	124.9	112.5
26	81.2	72.2	65.0	108.2	96.1	86.6	146.2	129.9	117.0
27	84.4	74.9	67.5	112.3	99.8	89.9	151.9	134.8	121.5
28	87.5	77.7	70.0	116.5	103.4	93.2	157.5	139.8	126.0
29	90.6	80.5	72.5	120.7	107.2	96.6	163.1	144.8	130.5
30	93.7	83.2	75.0	124.9	110.9	99.9	168.7	149.8	135.0
31	96.9	86.0	77.5	129.0	114.5	103.2	174.3	154.8	139.5
32	100.0	88.8	80.0	133.2	118.3	106.6	180.0	159.8	144.0
33	103.1	91.5	82.5	137.4	122.0	109.9	185.6	164.8	148.5
34	106.2	94.3	85.0	141.5	125.6	113.2	191.2	169.8	153.0
35	109.4	97.1	87.5	145.6	129.3	116.5	196.8	174.8	157.5
36	112.5	99.9	90.0	149.8	133.0	119.9	202.5	179.8	162.0

1. Extra 20% seed not included in the above calculations. For 20% extra seed, multiply the above value by 1.20.

MP 4. Nutrient Deficiency in Chickpea

Mineral nutrient deficiencies in crop plants are identified by soil testing, detection of foliar symptoms, and plant analysis.

Soil testing. It is useful to determine the critical nutrient concentration of a soil by doing a soil test.

Foliar symptoms. Smith and Pieters (1983) recorded foliar deficiency symptoms by growing chickpea plants in a water culture solution in 2 L glass containers (4 L polythene containers for boron). The basal nutrient solution contained 3.0 mM KNO_3, 2.0 mM $Ca(NO_3)_2$,1.0 mM $MgSO_4$, 0.5 mM KH_2PO_4, 0.5 mM NaCI, 1 mg kg^{-1} Fe as iron citrate, 0.01 mg kg^{-1} Cu, 0.025 mg kg^{-1} Zn, 0.125 mg kg^{-1} Mn, 0.25 mg kg^{-1} B, and 0.005 mg $kg^{'1}$ Mo. Resin-purified water and AR-grade salts were used in N, P, K, Ca, Mg, S, and B treatments. Purified micronutrients and salts and Specpure-grade micronutrient salts were used for the Cu, Zn, Fe, and Mn deficiency treatments. Iron citrate was added to the solutions each week. The pH was maintained between 5.5 and 7.0. The solutions were aerated for five minutes every half an hour. The basal nutrient solution was modified to give a series of levels (three to six) of each deficiency or toxicity being studied. This enabled plants with a full range of severity of symptoms to be established.

Chickpea seedlings were germinated on acid-washed quartz chips. Three plants were established in each container. First, four-week-old plants were grown in a culture solution containing less than the basal-solution concentration of the relevant nutrient. The culture solutions were then changed and the range of nutrient's levels established. The solutions were replaced 14 days later. A control plant with all nutrients was grown for comparison. The foliar deficiency symptoms of different nutrients are given in Table 6.

Table 6. Foliar deficiency symptoms[1] of different nutrients In chickpea.

Element	Deficiency symptoms
Nitrogen (N)	Plants turn yellow-green with the older leaves at the base of the plant yellower than the upper ones. The stem develops a pink coloration at the base of the plant and on the sides that are directly exposed to light. When there is severe N deficiency, the pink coloration extends right up the stem to within one or two nodes from the top of the plant. A reddish-pink pigmentation also develops as a very fine margin around the serration of the leaflets, on the upper surface and edges.
Phosphorus (P)	Plants are smaller and dark green in color. The stem develops a reddish-purple anthocyanin pigmentation on the side exposed to direct light. This pigmentation darkens and intensifies later. A reddish-purple margin develops on the top edge and upper surface of the leaflets of the lower leaves. The affected leaflets lose color and become yellow-green or buff green. The discoloration starts from the lower leaflets of the lower leaves and spreads to the other leaflets and then to the leaves above. Some lower leaves show reddish-brown anthocyanin

on their upper surfaces which tends to accumulate at the tips and margins of the leaflets. Ultimately the leaves lose their color and turn bronze.

Potassium (K)

Symptoms first appear on the older leaves. Margins and tips of leaves show chlorosis i.e., turn yellow-green or reddish. The tips of affected leaflets show brown necrotic patches, and eventually they die, turning light brown and rolling inward towards the rachis. The leaflets then abscise and drop off. The stem develops a reddish-brown anthocyanin pigmentation, where it is exposed to direct light.

Calcium (Ca)

The affected plant roots are short and thick with dark brown or black tips. Slow development of the rachis and leaflets results in short leaves with fewer leaflets than in a normal plant. Leaflets develop necrotic spots 0.5 to 1.0 mm in diameter, more so on the upper surface. The rachis of the affected leaf withers, starting from the tip back towards the stipule. The growing points of stems of calcium deficient plants also wither and die. This results in the growing point curling downwards and the leaves subtended by the dead portion of the stem dying and sometimes falling off. Death of the growing point enhances development of small axillary buds which often wither later. The older plant parts remain dark green.

Magnesium (Mg)

Initially, magnesium-deficient plants develop light green chlorosis on young leaves and on those midway down the stem. On fully expanded leaves, the chlorosis becomes more severe on the distal half of the leaflet than the base. Later it spreads along the sides of the leaflet which turns yellow to yellow-green with a green area remaining around the midrib. In severe magnesium-deficient plants, the basal area of the leaflets remains green without any evidence of anthocyanin.

Sulfur (S)

In sulfur-deficient plants, chlorosis starts from the leaves at the top, while the leaves at the base remain dark green. Early sulfur deficiency is similar to nitrogen deficiency. However, when it is severe, chlorosis affects the entire plant. Some leaflets become completely yellow, die, and drop off. Red anthocyanin pigmentation is also seen on the stem.

Iron (Fe)

Symptoms first appear as chlorosis on the terminal three or four newly formed leaves. The leaflets of these leaves turn a uniform yellow-green. As the deficiency becomes severe, white or light straw-colored necrotic patches develop on the distal half of the leaflets of young leaves and stipules. These patches then enlarge and the affected leaves wither and die. The rachis withers from the tip back towards the base. The top two or three leaves die and turn white or light straw-colored. Such leaves collapse and fall off.

Copper (Cu)

The leaves remain dark green, but the top three or four leaves are small and slightly folded inward along the midrib. There are fewer leaflets per leaf (sometimes only 5 or 6). The growing point of the leaf usually withers and turns rust brown. Stem elongation is reduced and the terminal point is retarded, and it may wither, die, and turn rust brown.

Zinc (Zn)

Initially, the younger leaves become pale green followed by the formation of a reddish-brown pigmentation on the margins of the upper surface of

	the leaflets and on the lower parts of the stem. At a later stage, leaflets become light in color, and the reddish-brown pigmentation on the margins is reduced. Stipules of younger leaves become chlorotic with a reddish-brown margin. Plant growth is stunted.
Manganese (Mn)	The younger leaves turn light green followed by the appearance of light brown spots on the leaflet surfaces and stipules of leaves. These spots are 0.2 to 0.5 mm in diameter, and form mainly on the upper surface of leaflets, between the veins, giving the leaflets a pitted appearance. Leaflets and stipules of young expanding leaves develop long, light brown necrotic areas. The rachises of these leaves wither and die from base to tip, subtending leaflets withering at the same time. Plant growth is arrested. Light brown necrotic plates are formed around the terminal bud which soon dies. Manganese deficiency follows a similar course as calcium deficiency. Axillary bud development is enhanced but the buds die soon. An excess of manganese is toxic to chickpea. Such plants turn pale green and develop symptoms similar to iron deficiency. Brown necrotic areas are formed around the leaflets and stipules. Affected abscise and drop off.
Boron (B)	Deficient plants remain dark green in color. The first symptom is yellowing and bronzing of the tips and margins of leaflets of young, fully expanded leaves. This coloration spreads as the deficiency becomes acute, but the central area of the leaflets around the midrib remains dark green. The tips and margins of the affected leaves start to die, showing narrow straw-colored necrotic areas near the leaf margins. Later, small white necrotic spots of less than 0.2 mm diameter appear on the leaf surface. Severe boron deficiency results in a stunted plant with many axillary buds. The roots are also stunted and thick with dark tips. Excess boron in the soil is toxic to chickpea. The symptoms are visible on the leaflets of lower leaves. The tips and serrate margins of leaflets and tips of stipules become yellow. Light brown necrotic patches, 1 to 2 mm in diameter, develop on these yellow zones later. As the necrotic area expands, the distal one-third part of the leaflet withers and dies, often causing cupping of the affected leaflet. Such leaves abscise and drop. At a later stage, as the toxicity spreads, the whole leaflet turns yellow.
Molybdenum (Mo)	Deficient plants show chlorosis similar to that of nitrogen deficiency.

1. Ahlawat (1990) discussed the problems of diagnosing foliar disorders in chickpea. For example, nitrogen and molybdenum deficiencies show identical symptoms. Similarly, phosphorus deficiency and aluminium (Al) toxicity symptoms are similar. The symptoms of N, P, K, and Mg deficiencies appear initially on the older leaves, whereas those of Cu, Zn, and Mo are more on new leaves because of their tendency to accumulate these elements.

Source: Smith and Pieters 1983; Ahlawat 1990.

Plant analysis. Plant analysis is the most reliable method of diagnosing nutrient disorders. While interpreting the data of plant analysis, the age of the plant, the part analyzed and the environmental conditions should be considered. The values of nutrient concentrations at critical, adequate, high, toxic, and deficient levels in chickpea are given in Table 7.

Table 7. Nutrient concentration in chickpea plants.

Nutrient	Growth stage	Plant part	Deficient	Critical	Adequate	High	Toxic
N (%)	Veg.[1]	Whole shoot	-	2.3			
P (%)	Veg.	Whole shoot	-	0.24			>0.75
	45 DAS[2]	Whole shoot[3]	0.09-0.25	-	0.29-0.33		
	77 DAS	Whole shoot[3]	0.15-0.20	-	>0.26		
S (%)	Veg.	Whole shoot	-	0.15			
Cl (%)	Veg.	Whole shoot	-	-			>1.6
Cu (mg kg^{-1})	Veg.	Whole shoot	<4.0	-		4-35	>35
Zn (mg kg^{1})	Veg.	Whole shoot[3]	-	-		12-500	>510
	40 DAS	Whole shoot	-	30			
	Veg.	Whole shoot	<20	-			>520
Mn (mg kg^{-1})	77 DAS	Whole shoot	-	-		>120	
B (mg kg^{-1})	Veg.	Whole shoot	<10	40		>235	
Mo (mg kg^{-1})	Veg.	Whole shoot	<0.1	-			

1. Veg. = Vegetative. 2. DAS = Days after sowing. 3. Values obtained from soil culture.
Source: Katyal 1985; Reuter 1986.

MP 5. *Rhizobium* Inoculation Procedures

Different methods of *Rhizobium* culture application have been reported for seed and seedbed inoculation (Brockwell 1977, 1982; FAO 1984; ICRISAT 1992).

Seed Inoculation

Seeds are inoculated either by using slurry or by the pelleting method.

Slurry Inoculation. The *Rhizobium* culture (inoculant) is applied to the seed as a water suspension. It can also be mixed with moistened seed. The inoculated seed is dried in the shade before sowing. To coat the seed with the inoculant, a nontoxic adhesive such as gum acacia, sugar or methyl cellulose is used. This involves the following steps:

1. Prepare a slurry by adding 40 g of the inoculant in 300 mL of fresh water. Stir the contents well. Adhesion of the inoculant to the seed can be improved by adding 10% gum *(Acacia arabica)* in a 10% sugar solution or 1.5% aqueous methyl cellulose gel.

2. Pour this slurry on the seed (approximately 25 kg), and mix in a clean vessel or on a plastic sheet until all the seeds are uniformly coated.

3. Dry the seed in the shade for about an hour. Preferably sow the seed on the same day.

Note: To prepare cellulose gel, take 4.5 g of methyl cellulose and add to it 150 mL of hot water at 80°C and stir till it dissolves completely. Add cold water while stirring the gel to make up the required volume. Allow the gel to cool down and add peat inoculant.

Seed pelleting. To promote nodulation, chickpea seeds are coated with lime after slurry inoculation. Such coating protects the rhizobia from toxic substances in the seed coat as well as from unfavorable physical and chemical soil conditions. The procedure of seed pelleting is completed with the following steps:

1. Prepare a sticker solution of 1.5% aqueous methyl cellulose or 40% aqueous gum acacia solution and allow it to cool down to 30°C.

2. Mix 70 g of the inoculant with 300 mL of the sticker solution.

3. Pour the gum-inoculant mixture on 25 kg of seed and mix thoroughly to get an even coating of the seeds.

4. Add 3 to 4 kg of fine lime immediately to this mixture and mix until the seeds are evenly pelleted.

5. The pelleted seed can be stored at 20°C for a week. However, better results are obtained if sowing is done immediately after the pelleting.

Seedbed Inoculation

Inoculants, solid or liquid, can also be applied to the seedbed. This procedure is useful when seeds have been treated with a fungicide or when sprouted seeds are used for sowing.

Solid inoculant

Solid inoculant is prepared by coating a granulated material (sand) with the peat inoculum in an adhesive. The procedure involves the following steps:

1. Prepare a slurry using three packets of inoculant (70 g each) in a 900 mL solution of available adhesive following the slurry inoculation procedure discussed earlier.

2. Arrange coarse sand with granules of 1-3 mm diameter (about 300 kg ha').

3. Mix the inoculant slurry with the sand until the granules are evenly coated. Dry the material in the shade with intermittent mixing until it becomes particulate and free-flowing. For small-scale operations, seed-coating may be done manually on a polyethylene sheet. Large-scale operations require a concrete mixer.

4. The inoculant-coated sand is applied in seeding furrows by hand or by using a fertilizer drill drawn by bullocks or a tractor.

Liquid Inoculant

In this procedure, a peat culture of *Rhizobium* is suspended in water and applied in seeding furrows using a low-gravity-flow applicator or a sprayer. The procedure involves the following steps:

1. Suspend three packets of inoculant (70 g each) in 600 L of water when the crop is sown under irrigated conditions. Under rainfed conditions, 3000 L of water ha' is required to ensure proper distribution of the *Rhizobium* culture.

2. Apply the inoculant suspension uniformly in the seeding furrows at the time of sowing, using a knapsack sprayer with a modified nozzle or without a nozzle to allow free flow of the liquid. In small-scale operations, the inoculant suspension is applied using a 5 L plastic container with an attached flexible delivery rubber tube.

Precautions

1. When seed is treated with pesticide, it is better to go in for seedbed inoculation to avoid the toxic effects of pesticides on rhizobia.

2. Superphosphate is toxic to *Rhizobium* bacteria. Therefore, do not mix it with the slurry-inoculated seed. However, lime-pelleted seed can be mixed with superphosphate before sowing.

3. Store the inoculum in a cool place (4°C).

4. A good-quality seed inoculum should contain at least 10" rhizobia g' of carrier. At least 10" rhizobia seed' or more are required.

5. When liquid inoculation is done, it is necessary to use at least 600 L of water ha^{-1} to ensure even distribution of rhizobia.

6. Do not prepare a large amount of inoculum at one time if sowing is to be done on different dates. After taking the required quantity, seal the inoculant packet with tape and store in a cool (4°C) place.

7. Use the inoculum before the expiry date.

MP 6. Weed Management

Weed management depends on the technology available, the cropping system, and the farmer's resources. Weed control is possible through direct methods — hand weeding, pre- or postemergence herbicide application — as well as indirect methods — appropriate field preparation, soil-moisture regulation, suitable sowing methods, and fertility management (Bhan and Kukula 1987). Sadaphal (1988) concluded that weed control for up to 60 days after sowing is essential to minimize competition from weeds.

Mechanical methods

Weeding is done using a flat chisel (*khurpi*), sickle, hand hoe, wheel hoe, or any other interrow cultivator. Two or three weedings are required during early crop growth. The first mechanical operation is carried out three to four weeks after sowing. The second weeding is done six to eight weeks after sowing and the third nine to twelve weeks after sowing (Bhan and Kukula 1987). In some cases, one weeding after 25-30 days of sowing is adequate (Ali 1989b). Sadaphal (1988) reported that weeding at 30 and 60 days after sowing was as good as the best herbicidal treatment, but yielded slightly less.

Chemical methods

Chickpea weed control on large farms is mainly herbicidal. The herbicides used before sowing, during pre- and postemergence stages are listed in Table 9.

Table 9. Herbicides to control weeds of chickpea.

Herbicide	Rate in a.i. ha^{-1}	Reference
Presowlng		
Trifluralin	0.40 L* or 1.0 kg	Sadaphal(1988)
Triallate	0.40 L*	Mahoney (1981)
Oxyfluorten+	0.36 L*	
Preemergence		
Pendimethalin	1.5 kg	
Diuron	0.30 kg*	Mahoney (1981)
Alachlor	1.5 kg	Sadaphal(1988)
Tribunil	1.5 kg	Yadav(1991)
Postemergence		
Prometryne	0.5 L* or 0.25 kg	Mahoney (1981)
Methabenzthiazuron	0.47 kg^{+}	

* = Provides limited weed control; + = Satisfactory control of broad-leaf weeds.

Preemergence application of pendimethalin at 0.75 kg ha^{-1} or presowing incorporation of fluchloralin at 0.75 kg ha^{-1} was quite effective in chickpea weed control (Ali 1989b).

References

Abbas, A.I. 1990. Status of chickpea production in Iraq. Pages 293-294 *in* Chickpea in the nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center,India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Agrawal, S.C., and Sharma, C.P. 1979. Recognizing micro nutrients disorders of crop plants on the basis of visual symptoms and plant analysis. Lucknow, India: Department of Botany, Lucknow University. 72 pp.

Ahlawat, I.P.S. 1990. Diagnosis and alleviation of mineral nutrient constraints in chickpea. Pages 93-100 *in* Chickpea in the nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Ahlawat, I.P.S., Singh, A., and Saraf, S.C. 1981. It pays to control weeds in pulses. Indian Farming 31:11-13.

All, M. 1988. Response of chickpea genotypes to population densities and atonik sprays under late sown conditions. Indian Journal of Pulses Research 1 (2):128—133.

All, M. 1989a. Consolidated report on *rabi* pulses: Agronomy. Directorate of Pulses Research, ICAR, Kanpur, U.P. India. (Limited distribution.)

Ali, M. 1989b. Management of production inputs for sustained productivity.of chickpea. Pages 157-158 *in* Abstracts: Proceedings of the International Symposium on Natural Resources Management for a Sustainable Agriculture, 6-10 Feb 1990, IARI, New Delhi, India. New Delhi, India: Indian Society of Agronomy.

Anonymous, 1976. Annual report of 1975 on grain legumes. Tehran University, School of Agriculture, Karaj, Iran: Tehran University.

Arakeri, H.R., Chalam, G.V., Satyanarayana, P., and Donahne, L. 1959. Soil management in India. Bombay, India: Asia Publishing House.

Arihara, J., and Ae, N. 1988. Response of chickpea, pigeonpea, and sorghum to method of phosphorus application in a Vertisol. Pages 22-23 *in* Phosphorus in Indian Vertisols: summary proceedings of a workshop, 23-26 Aug 1988, ICRISAT Center, India (Sahrawat, K.L., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Arihara, J., Ae, N., and Okada, K. 1991. Improving responses of chickpea and pigeonpea to phosphorus application in Vertisols and Alfisols. Pages 157-167 *in* Phosphorus nutrition of grain legumes in the semi-arid tropics (Johansen, C., Lee, K.K., and Sahrawat, K.L., eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Arvadia, M.K., and Patel, Z.G. 1988. Influence of date of sowing on growth and yield of gram (*Cicer arietinum* L.) under different fertility levels. Gujarat Agricultural University Research Journal 13(2).65-66.

Asaduzzamam, S.M., Morshed, G., and Slkder, F.S. 1989. Performance of seeding ratios on the yield of wheat and chickpea mixed cropping at Kanaipur, Faridpur. Page 54 *in* Proceedings of the 14th Annual Bangladesh Science Conference. Section 1. Dhaka, Bangladesh: Bangladesh Association for the Advancement of Science.

Auld, P., and Lee, G.A. 1981. Chickpea a potential pulse crop for northern Idaho. Current Information Service. Idaho Agricultural Experiment Station No. 570.

Autkar, K.S., Vyas, J.S., and Wanjari, K.B. 1991. Studies on chickpea-based intercropping under irrigated conditions. Annals of Plant Physiology 5(1): 103-109.

Baldev, B. 1988. Origin, distribution, taxonomy and morphology. Pages 3-51 *in* Pulse crops (Baldev, B., Ramanujam, S., and Jain, H.K., eds.). New Delhi, India: Oxford and IBH Publishing Company.

Barik, T., Shoo, K.C., Dalbehera, M., Rout, D., and Pradhan, L. 1991. Response of Bengal gram varieties to date of sowing and Jalshakti. Environment and Ecology 9(1):288-289.

Bejiga, G. 1990. Recent advances in chickpea improvement and prospects for the nineties. Pages 265-266 *in* Chickpea in the nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Bejiga, G., and Tullu, A. 1982. The influence of planting dates on the yield of three chickpea (*Cicer arietinum*) varieties. Ethiopian Journal of Agricultural Sciences 4:61-66.

Bennett, D., and McNeil, D.W. 1985. Effect of time of planting on irrigated chickpea yields in Northern Australia. International Chickpea Newsletter 12: 19-21.

Bernal, V.J.A. 1981. Control of bindweed (*Convolvulus arvensis* L) in chickpea through incorporation and injection of four herbicides in Costa de Hermosalto, Sonora. *In* Memorias II Congress nacional de la Ciencia de la Malaza (Quoted in Weed Abstracts 32:342, 1983).

Bezuneh, T. 1975. Status of chickpea production and research in Ethiopia. Pages 95-101 *in* Proceedings of the International Workshop on Grain Legumes, 13-16 Jan 1975, ICRISAT, Hyderabad, India. International Crops Research Institute for the Semi-Arid Tropics.

Bhan, V.M., and Kukula, S. 1987. Weeds and their control in chickpea. Pages 319-328 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Bhattacharya, P., and Sengupta, K. 1984. Effect of seed-dressing fungicides on nodulation and grain yield of chickpea. International Chickpea Newsletter 11:41-44.

Borgohaln, M., and Agrawal, S.K. 1986. Influence of rates and sources of phosphorus and irrigation levels on yield and yield attributes of kabuli gram (*Cicer arietinum* L). Indian Journal of Agronomy 31 (3):229-234.

Brockwell, J. 1977. Application of legumes seed inoculants. Pages 277-309 *in* A treatise on nitrogen fixation (Hardy, R.W.F., and Gibson, A.H., eds.). New York, USA: John Wiley and Sons.

Brockwell, J. 1982. Inoculation methods for field experiments and farmers. Pages 211-221 *in* Nitrogen fixation in legumes (Vincent, J.M., ed.). New York, USA: Academic Press.

Calcagno, F., Gallow, G., Venora, G., laiani, M., and Raimando, 1.1988. Effect of plant density on seed yield and its components for ten chickpea genotypes grown in Sicily, Italy. International Chickpea Newsletter 18:29-31.

Chandra, S. 1980. The effect of edaphic factors on chickpea. Pages 97-105 *in* Proceedings of the International Workshop on Chickpea Improvement, 28 Feb - 2 Mar 1979, ICRISAT, Hyderabad, India: International Crops Research Institute for the Semi-Arid Tropics.

Corby, R. 1981. Seeds of Leguminosae. Pages 913-915 *in* Advances in legumes systemics. Part 2 (Polhill, R.M., and Raven, P.H., eds.). Kew, UK: Royal Botanic Gardens.

Covell, S., Eilis, R.H., Roberts, E.H., and Summerfleld, R.J. 1986. The influence of temperature on seed germination rate in grain legumes. I. A comparison of chickpea, lentil, soybean, and cowpea at constant temperature. Journal of Experimental Botany 37:705-715.

Cubero, J.I. 1975. The research on chickpea (*Cicer arietinum*) in Spain. Pages 117-122 *in* Proceedings of the International Workshop on Graih Legumes, 13-16 Jan 1975, ICRISAT, Hyderabad, India: International Crops Research Institute for the Semi-Arid Tropics.

Cubero, J.I. 1987. Morphology of chickpea. Pages 35-66 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Daftardar, S.Y., Kumbhar, D.D., and Deshpande, A.N. 1988. Phosphorus utilization of Missouri rock phosphate by legume sequences. Page 87 *in* The use of rock phosphate in west coast soils: proceedings of a seminar, 29 Jan 1988, University of Agricultural Sciences, Bangalore, India.

Dahiya, B.S. 1974. Crossing without emasculation in chickpea. Indian Journal of Genetics and Plant Breeding 34:206-207.

Deore, B.P., Bharud, R.W., and Kharde, V.N. 1989. Physiological basis for yield differences in chickpea undeT different seeding periods. Annals of Plant Physiology 3(2):181-187.

Department of Agriculture, 1977. New South Wales, Australia. Annual Report 1976-77. 226 pp.

Dhingra, K.K., Grewal, D.S., and Dhillon, M.S. 1990. Competitive ability of raya *(Brassica)* and chickpea (*Cicer arietinum*) in different intercropping patterns and row directions. International Journal of Tropical Agriculture 8(4):282-288.

Dhingra, K.K., Sekhon, H.S., and Trlpathl, H.P. 1978. Pulses agronomy. Pages 29-39 *in* Progress Report 1977-78. Department of Plant Breeding, Ludhiana, India: Punjab Agricultural University.

Diaz, C.A. 1979. Identification and quantitative analysis of weeds in rice, sugarcane, cotton, and chickpea. Weed Abstracts 28:207.

Dravid, M.S., and Goswami, N.H. 1987. Effect of salinity, fertility, and variety on growth and nutrient uptake by chickpea (*Cicer arietinum* L). Journal of Nuclear Agriculture and Biology

16(2):69-72.

Dumbre, A.O., and Deshmukh, R.B. 1983. Yield of gram varieties affected by sowing dates, fertilizer application, and irrigation. Journal of Maharashtra Agricultural Universities 8:300.

Duron Noriega, L.J. 1986. [Determination of hydric regimes for chickpea in coarse soil on the Hermisillo, Sonora Coast.] (Es.) Agricultura Tecnica en Mexico 12(1):105—120.

Duschak, M. 1871. Zur Botanik des Talmud. I. Neuer, Pest:105-106.

Efimov, N.M. 1991. [Chickpeas in the kulunda steppe.] (In Ru. Summary in En.) Sibirskii Vevstinik Sel'kokuozyanistvennoi Nauki 3:48-52.

Eshel, Y. 1967. Effect of sowing date on growth and seed yield components of chickpea {*Cicer arietinum* L). Israel Journal of Agricultural Research 17:193-197.

Eshel, Y. 1968. Flower development and pollen viability of chickpea (*Cicer arietinum* L). Israel Journal of Agricultural Research 18:31-33.

Eshel, Y., Ohall, I., Yeger, D., and Badulah, G. 1979. Selective weed control in chickpea. Phytoparasitica 92:147.

FAO (Food and Agriculture Organization of the United Nations). 1984. Legumes inoculants and their use. A pocket manual jointly prepared by NifTAL, USA, and USA Fertilizer and Plant Nutrition Service, Land and Water Development Division in association with FAO Crop and Grassland Production Service, Rome, Italy: Food and Agriculture Organization.

FAO (Food and Agriculture Organization of the United Nations). 1992. Tapes about statistics of food crops. Rome, Italy: Food and Agriculture Organization.

Farah, S.M., Arar, A., and Miller, D.E. 1988. Water requirement and irrigation management of pea, lentil, faba bean, and chickpea crops. Pages 271-278 *in* World crops (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Gaur, B.L., and Choudhary, M.K. 1993. Effect of irrigation and moisture conserving substances on yield and water-use efficiency of gram *(Cicer arietinum).* Indian Journal of Agricultural Sciences 63(12):833-835.

Gelgy, J.R. 1969. Trials in cereals crops in Morocco with a view to the destruction of wild oats and other resistant weeds. Presented at the Conference Sur la Probleme des Mauvaises Herbes et les Moyens de Lutte, Tunis. 10 pp.

Graf, S., Klelfeeld, Y., Berguttl, A., and Retig, B. 1982. Dodder control in chickpeas. Hassadeh 62:1388-1389.

Gupta, J.N., Gupta, S.R., and Dutta, T.R. 1977. The influence of various densities of *Asphodelus tenuifolius* Cans. and *Chenopodium album* L. on gram crop. Abstract papers. Weed Science Congress and Workshop. 44 pp.

Gupta, M.L., and Meena, K.C. 1989. Studies on intercropping of chickpea (*Cicer arietinum*) and safflower (*Carthamus tinctorius* L.) under different systems of planting and irrigation levels. Page 201 *in* Abstracts: Proceedings of the International Symposium on Natural Resources Management for a Sustainable Agriculture, 6-10 Feb 1990, IARI, New Delhi, India. New Delhi, India: Indian

Society of Agronomy.

Gupta, N., and Singh, R.S. 1983. Response of Bengal gram (*Cicer ahetinum* L.) to nitrogen, phosphorus, and sulphur. Journal of Indian Society of Soil Sciences 31:156-159.

Habibl, A. 1990. Status of chickpea (*Cicer ahetinum*) in Afghanistan. Pages 299-300 *in* Chickpea in the nineties: proceedings of the Second International workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Hamidullah, J., Slddique, M., and Dast, Z. 1989. Response of chickpea to fertilizer and *Rhizobium* inoculation in rainfed soils of the North West Frontier Province, Pakistan. International Chickpea Newsletter 20:20-21.

Haqqani, A.M., Malik, B.A., Tahir, M., and Hussain, S.A. 1987. Effect of seeding depth on yield and yield determinants of three chickpea genotypes. Legumes.Research 10(1):11-12.

ICARDA (International Center for Agricultural Research in the Dry Areas). 1979. Annual report—weed control research in northern Syria. Aleppo, Syria:ICARDA. 43 pp.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1987. Agronomic practices to optimize yield of chickpea (Bengal gram) in peninsular India. Legumes Program, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT. 8 pp. (Limited distribution.)

ICRISAT (International Crops Research Institute for the Semi-Arid tropics). 1992. Methods of rhizobial inoculation. Legumes Program, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT. 10 pp. (Limited distribution.)

Idri, M., Mahmood, T., and Malik, K.A. 1989. Response of field-grown chickpea *(Cicer ahetinum* L.) to phosphorus fertilization for yield and nitrogen fixation. Plant and Soil 114(1):135-138.

Islam, M.N. 1989. Studies on chickpea and linseed mixed cropping. Page 92 *in* Proceedings of the 14th Annual Bangladesh Science Conference. Section 1. Dhaka, Bangladesh.Bangladesh Association for the Advancement of Science.

Kaiser, W.J., and Hannan, R.M. 1985. Effect of planting date and fungicide seed treatment on the emergence and yield of *kabuli and desi* chickpeas in eastern Washington state. International Chickpea Newsletter 12:16-18.

Kalbhor, H.B., Rasal, P.H., and Patll, P.L. 1988. Effects of Zn and Mn on nodulation and yield of gram. Journal of Maharashtra Agricultural Universities 13(2):213—214.

Kar, P.C., Patro, G.K., and Mohanty, K. 1989. Effect of levels of fertilizers on growth and yield of Bengal gram. Current Research 18(6):80-81.

Katyal, J.C. 1985. Research achievements of All India Coordinated Scheme of Micronutrients in Soils and Plants. Fertilizer News 30(4):67-80.

Kay, D.E. 1979. Chickpea (*Cicer ahetinum*). Pages 48-71 *in* Crop and Product Digest. No. 3, Food Legumes. London, UK: Tropical Product Institute.

Khaleque, M.A., Kamal, A.M.A., and Zaman, S.M. 1990. Effect of intercropping maize with chickpea as the main crop. Progressive Agriculture, Bangladesh 1(1):77-81.

Khokar, R.K., and Warsl, A.S. 1987. Fertilizer response studies in gram. Indian Journal of Agronomy 32(4):362-364.

Kolar, J.S., Sandhu, K.S., and Gurkirpal Singh. 1982. Efficiency of some substituted urea herbicides for control of weeds in irrigated chickpea. Pesticides 16:14-15.

Kostrlnskl, J. 1974. Agricultural Research Organization. Special Publication. Volcani Center, No. 34. 51 pp.

Kovachev, V., Makarov, H., and Radakov, P. 1968. Trials with chemical weed control in chickpea. Rastavniev'dni Nauki 5:115-121.

Ladlzlnsky, G. 1975. A new *Cicer* from Turkey. Notes from the Royal Botanic Gardens, Edinburgh 34:201-202.

Mahler, R.L., Saxena, M.C., and Aeschllmann, J. 1988. Soil fertility requirements of pea, lentil, chickpea, and faba bean. Pages 279-289 *in* World crops (Summerfield, R.J., ed.). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Mahoney, J.E. 1981. Herbicide tolerance in chickpeas. International Chickpea Newsletter 5:7-8.

Malty, P.K., and Jana, P.K. 1987. Effect of irrigation at different physiological growth stages on yield, yield attributes, and consumptive water use of gram, lentil, and pea. Indian Agriculturist 31(1):43-48.

Mane, B.M., and Jadhav, A.S. 1991. Dry matter accumulation and nodulation of gram influenced by fertilizers and plant densities. Journal of Maharashtra Agricultural Universities 16(1):39-42.

Mohamed, A.K. 1990. Effect of planting method, irrigation and nitrogen fertilizer application on grain yield and yield components of chickpea (*Cicer arietinum*) in Shandi area, Sudan. Acta Agronomica Hungarica 39(3-4):393-399.

Moolani, M.K., and Chandra, S. 1970. Gram cultivation in Haryana. Bulletin of the Haryana Agricultural University, Hisar, India. 15 pp.

Murray, G.A., and Auld, D.L. 1987. Effect of seeding rate, row spacing and seed size on chickpea yield and seed size. Journal of Applied Seed Production 5:10-17.

Naresh, R.K., Singh, O.P., and Gupta, R.K. 1985. Growth and yield contributing parameters in relation to different irrigations in chickpea. Indian Journal pf Plant Physiology 28(4):323-330.

Pal, A.K. 1986. Interaction of *Rhizobium* inoculation with phosphate and molybdenum application on chickpea (*Cicer arietinum*) in rainfed condition. Environmental Ecology 4(4):642-647.

Pala, M., and Matar, A. 1988. Soil test calibration with N and P for wheat under dryland conditions in Syria. Pages 55-66 *in* Soil test calibration in West Asia and North Africa: proceedings of the Second Regional Workshop, 1-6 Sep 1987, Ankara, Turkey (Matar, A., Soltanpour, P.N., and Chouinard, A., eds.). Allepo, Syria: International Center for Agricultural Research in the Dry Areas.

Pala, M., and Mazld, A. 1992. On-farm assessment of improved crop production practices in north west Syria. I. Chickpea. Experimental Agriculture 28(2):175-184.

Palled, Y.B., Chandrashekharalah, A.M., and Radder, G.D. 1985. Response of Bengal gram to moisture stress. Indian Journal of Agronomy 30:104-106.

Paramanik, M.H.R., Khan, M.A.H., Mushl, A.A.A., and Sadeque, M.A. 1990. Optimum plant population for chickpea. Progressive Agriculture, Bangladesh 1 (1):61—67.

Parihar, S.S. 1990. Yield and water use of chickpea (*Cicer arietinum*) as influenced by irrigation and phosphorus. Indian Journal of Agronomy 35(3):251-257.

Patel, R.G., Patel, H.C., Patel, M.P., and Patel, R.B. 1989. Effect of nipping and levels of phosphorous, on yield and economics of gram in clayey soils of south Gujarat. Gujarat Agricultural University Research Journal 15(1):77-78.

Patel, R.S., and Patel, Z.G. 1991. Effect of FYM, N, P and *Rhizobium* inoculation on the growth and yield of gram (*Cicer arietinum* L). Annals of Agricultural Research 12(2):200-202.

Paturda, J.T., and Phirka, P.S. 1990. Effect of fertilization and harvesting time on post-harvest characteristics of Bengal gram (*Cicer arietinum* Linn.). Legume Research 13(2):53-58.

Penaloza, H.E. 1984. The chickpea grain yield record under rainfed conditions in Chile. International Chickpea Newsletter 11:24-25.

Perur, N.G., and Mlthyantha, M.S. 1985. Soils of Karnataka and their management. Pages 177-207 *in* Soils of India and their management (Alexander, T.M., ed.). 2nd edn. New Delhi, India: Fertilizer Association of India.

Photiades, I. 1984. The effect of sowing date and plant population on the performance of chickpeas. Miscellaneous Reports No.4. Agricultural Research Institute. Nicosia, Cyprus: Ministry of Agriculture and Natural Resources. 5 pp.

Prabhakar, M., and Saraf, C.S. 1989. Management of supplemental irrigation and Missouri rock phosphate in conjunction with phosphate solubilizing bacteria as a source of phosphorus for improved productivity of chickpea (*Cicer arietinum* L.). Pages 96-97 *in* Abstracts: Proceedings of the International Symposium on Natural Resources Management for a Sustainable Agriculture, 6-10 Feb 1990, IARI, New Delhi, India. New Delhi, India: Indian Society of Agronomy.

Prabhakar, M., and Saraf, C.S. 1991. Effect of irrigation regimes and management of phosphorus sources on yield biomass and water use of chickpea. Journal of Maharashtra Agricultural Universities 16(2):221-223.

Prasad, K., and Singh, V. 1987. Response of Bengal gram to soil moisture regimes at sowing and fertilizers. Indian Journal of Agronomy 32(1):30-33.

Pundir, R.P.S., Rao, K.N., and van der Maesen, L.J.G. 1985. Distribution of qualitative traits with world germplasm of chickpea (*Cicer arietinum* L). Euphytica 34:697-703.

Pundir, R.P.S., and Reddy, K.N. 1984. Comparison of cross pollination methods in chickpea. International Chickpea Newsletter 11:9-11.

Pundir, R.P.S., Reddy, K.N., and Mengesha, M.H. 1988. ICRISAT chickpea germplasm catalog: Evaluation and analysis. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Quayyum, M.A., Akada, M.E., and Karim, M.E. 1987. Row spacing and number of rows of chickpea grown in association with maize (*Zea mays* L.). Bangladesh Journal of Agriculture 12(4):223-230.

Ral, R., and Prasad, V. 1983. Effect of pyrite as an amendment in calcareous saline-alkali soil and its effects on microbial population, nodulation, leghaemoglobin, and grain yield of chickpea (*Cicer arietinum* L.) with and without phosphorus. Indian Journal of Agricultural Chemistry 6:221-226.

Rajendran, S., Jha, D., and Ryan, J.G. 1982. Fertilizer responsiveness of chickpeas in India: An analytical review. Economics Program Progress Report no. 34, Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 35 pp.

Ram, P.C., Garg, O.P., Singh, B.B., and Maurya, B.R. 1989. Effect of salt stress on nodulation, fixed nitrogen partitioning, and yield attributes of chickpea (*Cicer arietinum* L). Indian Journal of Plant Physiology 32(2):115-121.

Rashld Shah, M.A., and Yousuf, M.A. 1987. Effect of different dates and rates of sowing on the yield of newly developed chickpea. Pages 4-5 *in* proceedings of the 12th Annual Bangladesh Science Conference. Section 5. Dhaka, Bangladesh: Bangladesh Association for the Advancement of Science.

Reuter, D.J. 1986. Temperate and sub-tropical crops. Pages 38-99 *in* Plant analysis—an interpretation manual (Reuter, D.J., and Robinson, J.B., eds.). Melbourne, Australia: Inkata Press.

Roberts, E.H., Summerfield, R.J., Minchln, F.R., and Hadley, P. 1980. Phenology of chickpeas (*Cicer arietinum*) in contrasting environments. Experimental Agriculture 16:343-360.

Roy, R.K., Sharma, R.P., and Singh, K.S.P. 1988. Effect of irrigation and foliar sprays of nutrients on the yield of late-sown chickpea. International Chickpea Newsletter 18:33-34.

Sadaphal, M.N. 1988. Agronomy of pulses. Pages 456-512 *in* Pulse crops (Baldev, B., Ramanujam, S., and Jain, H.K., eds.). New Delhi, India: Oxford and IBH Publishing Company.

Sadri, B., and Kahrobalan, A. 1990. Problems and solutions of chickpea production in Iran. Pages 295-296 *in* Chickpea in the nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Sarawgl, S.K., and Singh, N.P. 1989. Response of chickpea varieties to plant population and diammonium phosphate under late sown conditions. Indian Journal of Agronomy 34(1):61-63.

Sarkar, D., and Yllmaz, B. 1990. Effect of advancing sowing dates on chickpea production in Turkey. Pages 289-290 *in* Chickpea in the nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, M.C. 1980. Recent advances in chickpea agronomy. Pages 16-98 *in* Proceedings of the International Workshop on Chickpea Improvement, 28 Feb-2 Mar 1979, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, M.C. 1984. Agronomic studies on winter chickpeas. Pages 88-96 *in* Proceedings of the International Workshop on Chickpea Improvement. 28 Feb-2 Mar 1979, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, M.C. 1987. Agronomy of chickpea. Pages 207-232 *in* The chickpea (Saxena, M.C, and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Saxena, M.C., Sillm, S.N., and Singh, K.B. 1990. Effect of supplementary irrigation on winter and spring chickpea (*Cicer arietinum*) in a Mediterranean environment. Journal of Agricultural Science 114(3):281-293.

Saxena, M.C., and Singh, M.P. 1977. Studies on agronomic requirements of winter pulses. Pages 23-42 *in* Research on winter pulses. Experimental Station Bulletin no. 101. Pantnagar, U.P., India: G.B. Pant University of Agriculture and Technology.

Saxena, M.C., Subramaniyam, K.K., and Yadav, D.S. 1976. Chemical and mechanical control of weeds in gram. Pantnagar Journal of Research 1:112-116.

Saxena, M.C., and Yadav, D.S. 1975. Some agronomic considerations of pigeonpea and chickpeas. Pages 31-62 *in* Proceedings of the International Workshop on Grain Legumes, 13-16 Jan 1975, ICRISAT Center, Hyderabad, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, N.P. 1984. Chickpea. Pages 419-452 *in* The physiology of tropical field crops (Goldsworthy, P.R., and Fisher, N.M., eds.). UK: John Wiley and Sons Ltd.

Saxena, N.P., Krishnamurthy, L., and Sheldrake, A.R. 1988. Responses of chickpea to phosphorus applications on a Vertisol in semi-arid environment. Pages 23-24 *in* Phosphorus in Indian Vertisols:summary proceedings of a workshop, 23-26 Aug 1988, ICRISAT Center India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, N.P., Saxena, M.C., Johansen, C., Virmani, S.M., and Harris, H. (eds.) 1995. Adaptation of chickpea to West Asia and North Africa regions. ICRISAT/ICARDA publication. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, N.P., and Sheldrake, A.R. 1980a. Physiology of growth, development, and yields of chickpea in India. Pages 89-96 *in* Proceedings of the International Workshop on Chickpea Improvement, 28 Feb-2 Mar 1979, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, N.P., and Sheldrake, A.R. 1980b. Iron chlorosis in chickpea (*Cicer arietinum* L.) grown on high pH calcareous vertisols. Field Crops Research 3:211-214.

Sekhon, B.S., Sandhu, H.S., Thapar, S., Dhillon, K.S., and Rattan Singh. 1988. Effect of nitrogen at sowing and post-flowering stages on nitrogen assimilation and seed yield of chickpea. Plant Physiology and Biochemistry 15(1):92-96.

Setty, R.A., Jagannatha, V., and Channabasavanna, A.S. 1990. Suitable cropping sequences for localization area of Tungabhadra Project. Current Research 19(10):166—168.

Shakhawat, M.S., and Sharma, K.P. 1986. Response of Bengal gram to agronomic inputs under late sown conditions. Indian Agriculturist 30(1):59-62.

Sharma, P.B. 1987. Economics of rice-based intercropping systems in deep black soils. Indian Journal of Agronomy 32(4):335-340.

Sharma, R.P., Roy, R.K., Singh, A.K., and Jha, R.N. 1987. Production potential of wheat and gram in sole and mixed intercropping systems. Indian Journal of Agronomy 32(3):235-237.

Singh, A.K., Singh, S.B., and Singh, Y.P. 1989a. Response of chickpea and mungbean varieties to *rhizobium* inoculation and fertility levels in *diara* areas. Page 223 *in* Abstracts Proceedings of the International Symposium on Natural Resources Management for a Sustainable Agriculture, 6-10 Feb 1990, IARI, New Delhi, India. New Delhi, India: Indian Society of Agronomy.

Singh, B.P. 1983. Response of mustard and chickpea to moisture in soil profile and plant population on ardisols. Indian Journal of Agricultural Sciences 53:543-549.

Singh, G., and Bhushan, L.S. 1979. Water use, water-use efficiency and yield of dryland chickpea as influenced by P fertilization, stored soil water and crop season rainfall. Agricultural Water Management 2:299-305.

Singh, G., Koranne, K.D., Bhushan, L.S., Chand, S., and Ghosh, S. 1981. Advances in rainfed farming. Bulletin No. R-101 D-8, Central Soil and Water Conservation Research and Training Institute, Dehradun, India. 106 pp.

Singh, J., and Yadav, D.S. 1990. Studies on the wheat-based intercropping systems under rainfed conditions. Indian Journal of Agronomy 35(3):262-265.

Singh, K., Singh, O.N., Singh, U.N., and Chand, L. 1989b. Effect of Jalshakti on yield, nutrients uptake and moisture use by rainfed chickpea. Page 112 *in* Abstracts: Proceedings of the International Symposium on Natural Resources Management for a Sustainable Agriculture, 6-10 Feb 1990, IARI, New Delhi, India. New Delhi, India: Indian Society of Agronomy.

Singh, K.B. 1981. Yield potential of tall chickpeas at increased plant density. International Chickpea Newsletter 4:10-11.

Singh, K.B., and Auckland, A.K. 1975. Chickpea breeding at ICRISAT. Pages 3-18 *in* Proceedings of the International Workshop on Grain Legumes, 13—16 Jan 1975, ICRISAT Center, Hyderabad, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Singh, K.D., and Sharma, B.N. 1983. Balanced fertilizer use for pulses based on targeted yield concept. Legumes Research 6:55-60.

Singh, M., and Tllak, K.V.B.R. 1989. Field response of chickpea to inoculation of *Glomus versiformes.* Plant and Soil 119(2):281-284.

Singh, O.N., and Ram, H. 1990. Effect of phosphorus and sulphur application on protein and amino acid contents in chickpea. Indian Journal of Pulses Research 3(1):36-39.

Singh, P. 1989. Double-cropping system in relation to fertilizer application under rainfed condition. Farming Systems 5(3-4):55-60.

Singh, S., and Kamath, M.B. 1989. Soil and fertilizer phosphorus utilization from full basal, split and foliar application of phosphate by chickpea (*Cicer arietinum*) using isotope tracer. Indian Journal of Plant Physiology 32(2):110-114.

Smith, F.W., and Pieters, W.H.J. 1983. Foliar symptoms of nutrient disorders in chickpea *(Cicer arietinum).* CSIRO Australian Division of Tropical Crops and Pasture Technical Paper no. 23:1-11.

Smithson, J.B., Thompson, J.A., and Summerfield, R.J. 1985. Chickpea (*Cicer arietinum* L). Pages 312-390 *in* Grain legume crops (Summerfield, R.J., and Roberts, E.H., eds.). London: Cullims.

Summerfield, R.J., Vlrmani, S.M., Roberts, E.H., and Ellis, R.H. 1990. Adaptation of chickpea to agroclimatic constraints. Pages 61-72 *in* Chickpea in the nineties:proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Thakur, N.S., Raghuvansi, R.K.S., and Sharma, R.A. 1989. Response of irrigated chickpea to applied nutrients. International Chickpea Newsletter 20:19-20.

Thakur, R.N., and Jadhav, A.S. 1990. Effects of fertilizers and plant densities on the yield of gram. Journal of Maharashtra Agricultural Universities 15(2):238-239.

Thomas, M., and Vyas, S.C. 1984. Nodulation and yield of chickpea treated with fungicides at sowing. International Chickpea Newsletter 11:37-38.

Tlwari, V.N., and Pathak, A.N. 1988. Use of pyrites for increasing crop yields. Indian Farming 38(9):35-36.

Tlwari, V.N., Lehri, L.K., and Pathak, A.N. 1989. *Rhizobium* inoculation of legumes as influenced by phosphorus and molybdenum fertilization. Journal of the Indian Society of Soil Science 37(4)712-716.

Tomar, N.K., Yadav, D.S., Gupta, A.P., and Sharma, J.C. 1987. A review on fertilizer management in pulses. II. Winter pulses. Agricultural Reviews 8(2):100-108.

Tripathl, R.S. 1967. Mutual interaction of gram and two common weeds (*Asphodelus tunuifolius* Cav. and *Euphorbia dracunculoides* Lamk.). Tropical Ecology 8:105-109.

Tripathi, R.S. 1968. Comparison of competitive ability of certain weed species. Tropical Ecology 9:37-41.

van der Maesen, L.J.G. 1972. *Cicer* L, a monograph of the genus, with special reference to the chickpea (*Cicer arietinum* L), its ecology and cultivation. Mededelingen Landbouwhogeschool (Communications Agricultural University) Wageningen 72-110.

van der Maesen, L.J.G. 1987. Origin, history and taxonomy of chickpea. Pages 11-34 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Varughese, K., and Pathak, S.S. 1987. Response of chickpea (*Cicer arietinum* L.) to soil and foliar application of diammonium phosphate. Agricultural Research Journal of Kerala 25(2):285-287.

Veer, D.M., and Patil, P.L. 1987. Effect of Azolla manuring on yield of gram. Current Research Reporter, Mahatma Phule Agricultural University 3(1):107—108.

Vyas, S.C., and Joshl, L.K. 1975. A new record of parasitic dodder on chickpea. Current Science 44(19):401-402.

Yadav, D.S. 1991. Pulse crops (Production technology). New Delhi, India: Kalyani Publishers. 310 pp.

Yadav, D.S., Singh, V.K., and Varma, K.K. 1989a. Effect of sowing dates and plant densities on the performance of *kabuli* chickpea genotypes. Indian Journal of Pulses Research 2(2):172-174.

Yadav, H.D., Yadav, O.P., Dahlya, S.S., and Yadav, V.K. 1989b. Effect of different sodicity and phosphorus levels on germination, nodulation, and yield of chickpea (*Cicer arietinum* L.). Pages 283-284 *in* Abstracts: Proceedings of the International Symposium on Natural Resources Management for a Sustainable Agriculture, 6-10 Feb 1990, IARI, New Delhi, India. New Delhi, India: Indian Society of Agronomy.

Yadava, S.K., Singh, S.P., and Bhan, V.M. 1983. Weed control in chickpea. Tropical Pest Management 29:297-298.

Evaluation

Select the most appropriate answer. The correct answers are given at the end of the booklet.

1. Chickpea belongs to the genus
   a) Arachide.
   b) Cicereae.
   c) Cicer.
   d) Leguminosae.

2. The scientific name of cultivated chickpea is
   a) *Cicer arietinum.*
   b) *Cicer pinnatifium.*
   c) *Cicer reticulatum.*
   d) *Cicer cuneatum.*

3. The world hectarage (million ha) and production (million tons) of chickpea respectively are
   a) 5.0 and 5.0.
   b) 10 and 7.1.
   c) 12 and 8.0.
   d) 10 and 5.0.

4. The average productivity of chickpea in the world is
   a) 1000 kg ha^{-1}.
   b) 2000 kg ha^{-1},
   c) 700 kg ha^{-1}.
   d) 1500 kg ha^{-1}.

5. The highest production of chickpea is in
   a) Pakistan.
   b) India,
   c) Turkey.
   d) Ethiopia.

6. The highest productivity (kg ha^{-1}) of chickpea in the world is in
   a) India.
   b) Pakistan.
   c) Egypt.
   d) Ethiopia.

7. Most chickpea plants are covered with
   a) glabrous hairs.
   b) spines.
   c) whitish powder.
   d) viscid, glandular hairs.

8. The macrosperma *(kabuli)* type of chickpea plants have a seed mass of
   a) >10 g 100^{-1} seed.
   b) >15 g 100^{-1} seed,
   c) >20 g 100^{-1} seed.
   d) >25 g 100^{-1} seed.

9. The color and shape of macrosperma type chickpea seeds are
   a) green and round.
   b) white and round.
   c) white and oval.
   d) cream-colored and ramhead.

10. The macrosperma chickpea plants are
    a) medium-tall without anthocyanin and bearing white flowers.
    b) medium-tall with anthocyanin and bearing red flowers.
    c) short with anthocyanin and bearing white flowers.
    d) all the above (a, b, and c).

11. The optimum temperature for chickpea germination is
    a) 10-15°C.
    b) 15-20°C.
    c) 20-25°C.
    d) 28-30°C.

12. Germination of the chickpea seed is
 a) hypogeal. b) epigeal.

13. Chickpea roots can grow ________ in the soil.
 a) 30-60 cm deep b) 60-90 cm deep
 c) 90-120 cm deep d) 150-180 cm deep

14. Chickpea *Rhizobium* nodules are
 a) oval-shaped and red-colored.
 b) carotenoid type, branched laterally, and flattened.
 c) pinkish and round.
 d) like a small ball.

15. Chickpea plants have
 a) only primary branches.
 b) only secondary branches.
 c) primary and secondary branches.
 d) primary, secondary, and tertiary branches.

16. The primary branches in chickpea start from
 a) the ground level, and are thick, strong, and woody.
 b) buds located on the main shoot.
 c) secondary shoots.
 d) none of the above.

17. Chickpea leaves are
 a) trifoliate and compound.
 b) petiolate, compound, and uniimparipinnate.
 c) glabrous, serrate, and imparipinnate.
 d) imparipinnate and viscid.

18. The chickpea rachis is
 a) 1-2 cm in length supporting 3-5 leaflets.
 b) 2-3 cm in length supporting 6-8 leaflets.
 c) 3-7 cm in length supporting 10-15 leaflets.
 d) 7-9 cm in length supporting 20-25 leaflets.

19. The ending of the leaflets on the rachis is
 a) terminal.
 b) subterminal.
 c) to one side.
 d) with the central vein continuing the rachis.

20. Chickpea leaflets are
 a) 5-6 cm long and 5-8 cm wide. b) 6-8 cm long and 9-10 cm wide,
 c) 8-17 mm long and 5-14 mm wide. d) 15-20 mm long and 20-25 mm wide.

21. The shape of the leaflet in chickpea is
 a) obovate to elliptical. b) oval-round.
 c) squarish oval. d) round.

22. Chickpea stipules are

a) long or round.

b) obovate to triangular in shape, and toothed.

c) hairy and round.

d) obovate to elliptical.

23. The external surface of the chickpea plant, except the corolla, is densely covered with glandular

a) stipules. b) hairs.

c) inflorescence. d) leaves.

24. The chickpea inflorescence is

a) an axillary raceme. b) a corymb.

c) an umbel. d) a capitulum.

25. Chickpea flowers are borne on the

a) branches. b) raceme.

c) rachis. d) axillary raceme by a pedicel.

26. In colored flowers, the floral peduncle and the racemal peduncle respectively are

a) red and yellow. b) yellow and pink.

c) purplish and green. d) white and pink.

27. The axillary inflorescences are shorter than the

a) flower. b) rachis.

c) stipules. d) subtending leaves.

28. The chickpea calyx is

a) dorsally gibbous at the base. b) ventrally gibbous at the base.

c) free. d) lanceolate.

29. The five sepals of chickpea flowers are subequal and lanceolate. The two dorsal (vexillar) sepals are closer to each other than the two lateral ones. The fifth one is

a) to one side. b) in the center.

c) separated from the others. d) obliquely placed.

30. Chickpea petals are

a) six, uniform, and colored.

b) five, polypetalous with a standard, two wings and two keels.

c) five, oval-shaped.

d) five, gamopetalous.

31. The standard petal (vexillum) is

a) obovate, wide, glabrous, and pubescent.

b) obovate with a short pedicel, 6-9 mm long, 4 mm wide.

c) rhomboid, 6-8 mm long, with a 2-3 mm pedicel.

d) two-thirds of the frontal side.

32. Chickpea plants have ten stamens in a
   a) free condition.
   b) diadelphous (9)+1 condition.
   c) diadelphous (8)+2 condition.
   d) none of the above.

33. Chickpea anthers are
   a) unicelled and round.
   b) multicelled and long.
   c) bicelled, basifixed, and round.
   d) bicelled and oblong.

34. The ovary of chickpea is
   a) multicarpellary, multilocular with central placentation.
   b) monocarpellary, unilocular with marginal placentation, superior, 2-3 mm long, and 1-15 mm wide.
   c) dorsifixed, ovate, and long.
   d) multicellular and inferior.

35. Generally, there are _____ seeds in a chickpea pod.
   a) one
   b) two
   c) three
   d) 1-3

36. The style of a chickpea flower is
   a) glabrous, 3-4 mm long, linear, and upturned.
   b) globose and capitate.
   c) smooth and erect.
   d) hairy, globose, and capitate.

37. The developmental stage of the chickpea bud when the stigma is immature and the anthers are still at the base is called
   a) hooded stage.
   b) closed stage.
   c) half-open stage.
   d) fading stage.

38. The developmental stage of the bud/flower when the corolla has elongated and the anthers are about half the height of the style is called
   a) hooded stage.
   b) closed stage.
   c) half-open stage.
   d) fully open stage.

39. Anthesis in chickpea takes place in the bud
   a) on the day the flower opens.
   b) after the flower opens.
   c) one day before the flower opens.
   d) two days after the flower opens.

40. The anthesis period in chickpea is
   a) 0600-0700 h.
   b)1300-1400 h.
   c) 0800-1700 h.
   d)1500-1600 h.

41. Low seed-setting in chickpea is mainly due to
   a) high temperature.
   b) low temperature.
   c) cloudy weather and high humidity.
   d) none of the above.

42. After pollination, mature pods are harvested after
   a) 30 days.
   b) 40 days.
   c) 50 days.
   d) 60 days.

43. After fertilization, pod formation starts in

a) 2-3 days. b) 3-4 days.
c) 5-6 days. d) 10-12 days.

44. In chickpea, the number of pods plant^{-1} varies between

a) 5 and 10. b) 15 and 25.
c) 30 and 150. d) 200 and 300.

45. The seed rate ha^{-1} for chickpea sowing depends on

a) the required plant density. b) seed mass.
c) germination percentage of the seed-lot. d) all the above.

46. The length and width of a chickpea seed ranges between ________ respectively.

a) 2-5 mm and 2-6 mm b) 4-12 mm and 4-8 mm
c) 6-8 mm and 3-5 mm d) 10-15 mm and 9-12 mm

47. The seed mass of chickpea varies between

a) 1 and 2 g seed^{-1}. b) 2 and 3 g seed^{-1}
c) 3 and 4 g seed^{-1}. d) 0.1 and 0.75 g seed^{-1}.

48. The seed shape in the chickpea varies from

a) angular, reticulated, and smooth. b) owl's head and pea-shaped.
c) spherical and squarish. d) all the above.

49. In the northern hemisphere, chickpea is grown between

a) 10°N and 15°N. b) 5°N and 15°N.
c) 20°N and 40°N. d) 30°N and 50°N.

50. The constraints at the seedling stage of chickpea grown on Vertisols of Southeast Asia are

a) cold and wet seedbeds. b) hot and dry seedbeds.
c) hot and saline seedbeds. d) all the above.

51. In Asia and the Mediterranean region, chickpea crop is adversely affected by.............. during the reproductive and maturity stages.

a) soil cracking and supraoptimal temperature
b) drought, salinity, and frost
c) drought, poor radiation, and frost
d) all the above

52. Chickpea growth and production are best in

a) deep or silty clay loams. b) calcic terrarosa.
c) deep black cotton soil. d) sandy soils.

53. Chickpea is highly sensitive to

a) drought and cold. b) sodicity and salinity.
c) poor soil aeration and waterlogging. d) all the above.

54. The soil factor that restricts outward movement of fixed nitrogen from the rhizobial nodules, and decreases translocation of nitrogen to the seeds and increases N accumulation in the leaves and pod walls is

a) calcium. b) iron.
c) salinity. d) zinc.

55. In the alluvial soils of the Indo-Gangetic plains, chickpea follows rainy-season crop(s) such as

a) pearl millet and sorghum. b) maize and sesame.
c) early paddy. d) all the above.

56. In West Asia, North Africa, and southern Europe, chickpea is grown in rotation with

a) wheat and barley. b) melons and sesame.
c) sorghum and maize. d) all the above.

57. In Ethiopia and the East African highlands, chickpea is grown in rotation with

a) barley and wheat. b) faba bean.
c) safflower, sorghum, and maize. d) both a and b.

58. In South and Central America, chickpea is grown in rotation with

a) maize. b) sesame.
c) wheat. d) all the above.

59. For chickpea cultivation on heavy soils, it is necessary to prepare a

a) fine seedbed. b) rough seedbed.
c) very fine seedbed. d) broadbed-and-furrow system.

60. To conserve soil moisture, it requires

a) deep plowing at the start of the rainy season.
b) deep plowing at the end of the rainy season.
c) deep plowing after the rainy season.
d) light plowing during the rainy season.

61. At ICRISAT Asia Center, chickpea is grown on a flat- or broadbed-and-furrow system at a density of

a) 5-10 plants m^{-2}. b) 15-20 plants m^{-2}.
c) 20-25 plants m^{-2}. d) 30-33 plants m^{-2}.

62. Higher plant densities are better for a chickpea crop, when it is sown

a) early. b) during mid season.
c) at the normal time. d) late.

63. The optimum plant population of chickpea depends upon

a) genotype. b) environmental conditions.
c) nutrients and irrigation. d) all the above.

64. Delayed sowing of chickpea results in

a) reduced growth. b) poor seed quality.
c) low yield. d) all the above.

65. The quantity of nitrogen fixed in chickpea is highly dependent on the soil

a) P level. b) K level.
c) NO_3-N level. d) Fe level.

66. The response to *Rhizobium* inoculation is more favorable when combined with the application of

a) N. b) P. c) K. d) Mn.

67. The water-absorbing polymer used for increasing the soil moisture level in chickpea is registered in India as

a) *Bradyrhizobium.*
b) Jalshakti.
c) biofertilizer.
d) organic fertilizer.

68. The symptoms of N, P, K, and Mg deficiencies in chickpea appear initially more on

a) new leaves.
b) stem.
c) old leaves.
d) none of the above.

69. The application of gypsum can increase chickpea germination, nodulation, and seed yield in

a) acidic soil.
b) sodic soil.
c) Vertisol.
d) Alfisol.

70. *Azolla pinnata* is applied to chickpea crop

a) at presowing.
b) at sowing.
c) at postsowing.
d) at any time.

71. The optimum rate of nitrogen (N) application in chickpea is

a) 5-10 kg ha^{-1}.
b) 10-15 kg ha^{-1}.
c) 15-25 kg ha^{-1}.
d) 40-50 kg ha^{-1}.

72. Application of N at postflowering stage

a) enhances nitrate reductase activity.
b) enhances yield.
c) reduces nitrate reductase activity.
d) both a and b.

73. Response to phosphorus application is more pronounced in chickpea when it is in combination with

a) nitrogens
b) *Rhizobium.*
c) irrigation.
d) all the above.

74. In rainfed conditions the best way to apply phosphorus to chickpea is by

a) mixing it in the top 15 cm of the soil.
b) band application 5 cm deep.
c) broadcasting on the upper surface.
d) all the above.

75. In general, the response of chickpea to potassium application is

a) high.
b) low.
c) no response.
d) both b and c.

76. Zinc deficiency in chickpea can be corrected with an application of zinc sulfate as

a) basal application.
b) band application.
c) foliar spray (0.5%).
d) dusting.

77. Iron availability is low in calcareous soils due to

a) drought stress.
b) waterlogging.
c) late sowing.
d) early sowing.

78. Manganese deficiency in chickpea occurs when its level reaches

a) above 10 mg kg^{-1}.
b) below 10 mg kg^{-1}.
c) above 15 mg kg^{-1}.
d) below 2.5%.

79. Copper availability is low in
a) calcareous and acidic soils.
b) saline and sodic soils.
c) coarse-textured soils.
d) all the above.

80. Lateritic soils with a high clay content are generally low in available
a) iron.
b) molybdenum.
c) zinc.
d) boron.

81. In chickpea, emasculation is done on the buds which are
a) in anthesis.
b) half open.
c) likely to be in anthesis after one day.
d) fading.

82. To protect chickpea seeds from seed and seedling diseases, they are treated with
a) captan at 1.0 g kg^{-1}.
b) carbendazim at 1.5 g kg^{-1}.
c) quintozene and thiram at 1.5 g kg^{-1}.
d) any one of the three above.

83. The optimum depth of sowing for chickpea is
a) 5-6 cm.
b) 7-8 cm.
c) 10-12 cm.
d) more than 15 cm.

84. Yield losses due to weeds in chickpea may be as high as
a) 10%. b)20%. c)50%. d)95%.

85. The most common weed(s) of chickpea is (are)
a) *Chenopodium album.*
b) *Polygonum* sp.
c) *Phalaris* sp.
d) all the three weeds above.

86. The most appropriate period for chickpea hand weeding is at
a) 10-15 days after sowing (DAS).
b) 15-20 DAS.
c) 25-30 DAS.
d) after 60 DAS.

87. Chickpea is better adapted to
a) low soil moisture.
b) no soil moisture.
c) high soil moisture.
d) all the above.

88. The most critical stage for drought stress in chickpea is the___________stage.
a) vegetative
b) flowering
c) flowering and pod development
d) maturity

89. Nipping induces more
a) branching.
b) growth and yield.
c) podding.
d) none of the above.

90. High levels of N and P application in chickpea generally
a) induces early flowering.
b) results in late flowering.
c) delays harvest and increases seed germination.
d) improves rhizobial activity.

Answers

1. c; 2. a; 3. b; 4. c; 5. b; 6. c; 7. d; 8. d; 9. d; 10. a; 11. d; 12. a; 13. d; 14. b; 15. d; 16. a; 17. b; 18. c; 19. b; 20. c; 21. a; 22. b; 23. b; 24. a; 25. d; 26. c; 27. d; 28. a; 29. c; 30. b; 31. a; 32. b; 33. c; 34. b; 35. d; 36. a; 37. b; 38. a; 39. c; 40. c; 41. c; 42. d; 43. c; 44. c; 45. d; 46. b; 47. d; 48. d; 49. c; 50. b; 51. c; 52. a; 53. d; 54. c; 55. d; 56. d; 57. d; 58. d; 59. b; 60. a; 61. d; 62. d; 63. d; 64. d; 65. c; 66. b; 67. b; 68. c; 69. b; 70. a; 71. c; 72. d; 73. d; 74. a; 75. d; 76. c; 77. b; 78. b; 79. d; 80. b; 81. c; 82. d; 83. c; 84. d; 85. d; 86. c; 87. a; 88. c; 89. d; 90. c.