Prospects of developing new genetic material and breeding methodologies for chickpea improvement

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Prospects of developing new genetic material and breeding methodologies for chickpea improvement[1]

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SUMMARY - In the past, limited genetic improvement was made in chickpea (*Cicer arietinum* L.). Some ways and means have been discussed to make the desired improvement. It is important to breed cultivars with multiple resistance in order to stabilize chickpea production. The wealth of genes present in the wild *Cicer* species await exploitation primarily in the multiple resistance breeding programme. New biotechnological tools, such as embryo rescue technique, are required to transfer genes from wild species to cultivated species. The current plant type in chickpea is unsuitable for producing high yields. New plant types for different situations are required to be tailored. In this context, increased biomass, input responsive cultivars, and types for high plant density deserve consideration. In the past twenty years, a reasonable number of germplasm accessions have been collected, but still more explorations are needed to collect landraces and wild relatives before they are lost. Some traits that are absent in germplasm collection need to be created either through induced mutation or through interspecific hybridization.

RESUME - *"Perspectives de développement de matériel génétique et de méthodologies de sélection nouveaux pour l'amélioration du pois chiche". Dans le passé, l'amélioration génétique a été très limitée chez le pois chiche (*Cicer arietinum *L.). Les moyens nécessaires pour réaliser les améliorations souhaitables sont discutés ici. Il est important de créer des cultivars à résistances multiples afin de stabiliser le rendement du pois chiche. Les ressources génétiques présentes dans les espèces sauvages du genre *Cicer *méritent d'être exploitées, tout d'abord dans les programmes de sélection pour des résistances multiples. De nouveaux outils méthodologiques, tels que le sauvetage d'embryons, sont nécessaires pour transférer des gènes d'espèces sauvages aux variétés cultivées. Le type de plante actuel du pois chiche n'est pas adapté à l'obtention de hauts rendements. De nouveaux types de plantes, adaptés à différentes situations, nécessitent d'être développés. L'attention devrait porter sur l'augmentation de biomasse, la réponse aux intrans et l'adaptation aux forts peuplements. Dans les vingt dernières années, un nombre raisonnable de génotypes ont été collectés, mais une plus large collecte est nécessaire pour préserver les variétés locales et les espèces sauvages avant qu'elles ne disparaissent. Certains caractères absents des ressources génétiques actuelles pourraient être créés soit par mutagénèse, soit par hybridation interspécifique.*

Introduction

Chickpea (*Cicer arietinum* L.) is a diploid species with 2n = 16 chromosomes. It is a self-pollinated crop with natural cross-pollination of less than one percent. It has been cultivated since at least 5450 B.C. (Helback, 1959). The crop probably originated in the region of south-eastern Turkey and adjoining area of Iran and the USSR. Two types of chickpea, namely desi (characterized by small, angular and coloured seeds) and kabuli (characterized by large, ram-head-shaped and beige coloured seeds), are grown in the world. Chickpea is primarily grown in four regions, viz. the Indian subcontinent, East Africa, the Mediterranean region and Latin America. The first two regions primarily grow desi type and the latter two regions kabuli type.

Since chickpea has been cultivated for at least 7000 years, man consciously or unconsciously selected im-

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proved types. The first record of a planned breeding programme is at the Imperial (now Indian) Agricultural Research Institute, Pusa, Bihar, India in 1905 (see Singh 1987 for historical development).

Though chickpea as the fifth most important grain legume crop after soybean, groundnut, dry bean, and dry pea has a long history of breeding, the resulting genetic improvement has been limited. This paper indicates areas which deserve attention by plant breeders and geneticists.

Breeding for stability in production

The chickpea is attacked by a number of diseases (ascochyta blight, fusarium wilt, root-rots, viruses), insects (pod borer, leaf miner, stored-pests), nematodes (cyst, root-knot, lesion), and parasites (*Orobanche* spp.). Heavy losses also occur from physical stresses, such as cold, heat, drought, and salinity. Significant crop improvement has been made in breeding for fusarium wilt and pod borer at ICRISAT, fusarium wilt in Mexico, ascochyta blight and cold at ICARDA (Singh, 1987) and viruses in California, USA. There are many other national programmes undertaking research in disease resistance. Most of this progress has been for a single stress, whereas in nature the crop is attacked by multiple stresses. Furthermore, most of the recently developed cultivars have resistance to a single race or a few races of a pathogen, therefore they are not universally resistant. Probably cultivars resistant to all existing races will never be developed, but they should be resistant to at least the common races of a country. Hence, multiple resistance should be of prime concern to scientists engaged in resistance breeding.

Breeding chickpea for multiple resistance is important to make the crop stable in production. Pedigree, backcross-pedigree or backcross methods are usually followed to develop resistance to a single stress. With the objective of combining the resistance to two stresses, two approaches are possible. Firstly, separate programmes are required to develop high yielding line with resistance to each stress separately followed by intercrossing between the finished material from the two programmes. Alternatively, high yielding lines may be developed with resistance to a single stress and resistance to another stress may be added through full or limited backcrossing (Fig. 1).

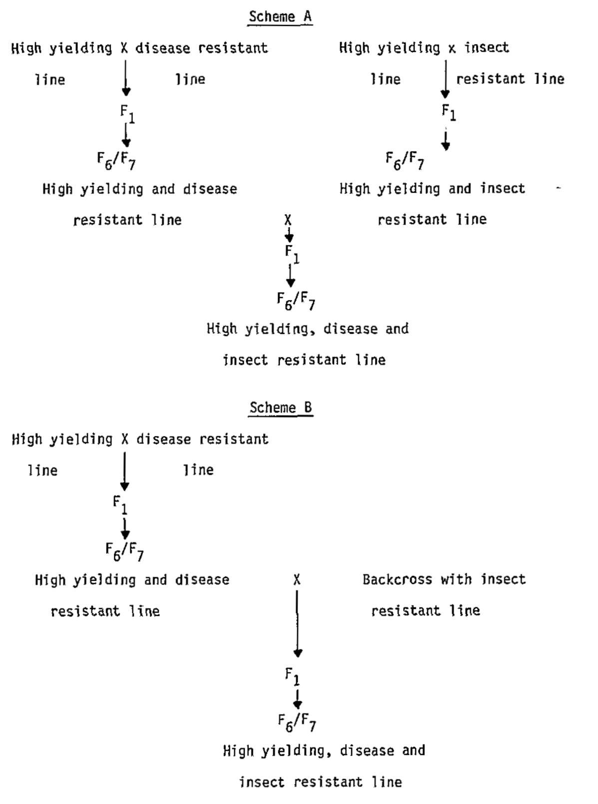

Fig. 1. In scheme A, through two separate programmes resistance is developed to two stresses and in scheme B high yielding and resistant line is developed for one stress followed by backcross to add resistance to second stress.

Wild *Cicer* species

Forty-two wild *Cicer* species have been reported (van der Maesen, 1987). ICRISAT has the largest collection of 14 species followed by nine species at ICARDA.

Evaluation of wild species

ICARDA has evaluated *Cicer* species for resistance to biotic and abiotic stresses (Table 1). High levels of resistance were found for *Ascochyta rabiei, Liriomyza cicerina, Callosobruchus chinensis, Heterodera ciceri,* and cold.

We have evaluated 130 collections of eight *Cicer* species for 32 morpho-agronomic traits. We have found that the wild species possess many useful traits besides genes for resistance, for example early maturity.

Table 1. Evaluation of the wild *Cicer* species against biotic and abiotic stresses at ICARDA.

Resistant to	*Cicer* species
Ascochyta rabiei	*C. judaicum* *C. bijugum* *C. pinnatifidum* *C. cuneatum*
Liriomyza cicerina	*C. yamashitae* *C. judaicum* *C. pinnatifidum* *C. chorassanicum* *C. cuneatum*
Callosobruchus chinensis	*C. judaicum* *C. echinospermum* *C. cuneatum*
Heterodera ciceri	*C. bijugum*
Cold	*C. bijugum* *C. reticulatum*

Cytology of *Cicer* species

Bahl (1987) reviewed research on chickpea cytology. We found that the chromosome number of the following ten species was 2n = 16: *C. arietinum, C. bijugum, C. canariense, C. chorassanicum, C. cuneatum, C. echinospermum, C. judaicum, C. pinnatifidum, C. reticulatum* and *C. yamashitae*. Karyo-morphology seems to differ widely across species.

Transfer of genes from wild to cultivated species

Previous attempts to cross the cultigen with wild *Cicer* species have failed to produce fertile plants with the exception of the cross between *C. arietinum* and *C. reticulatum* (Ladizinsky and Adler, 1976). In recent years much is expected from the use of embryo rescue technique to help plant breeders overcome barriers in interspecific crosses. Although the basic requirements for growth of plant cells and tissue culture are known (Davey and Thomas, 1975), fundamental problems of how to manipulate medium and environment to produce whole plants still exist. Another problem in the use of tissue culture is in selection of traits, such as maturity and yield. Despite many limitations at the moment there is a strong need to study cell and tissue culture technique, and embryo rescue technique for their use in chickpea breeding.

Increased biomass and yield potential

The average yield of chickpea in the world is low at between 600 and 700 kg/ha. Along with low average yield, the genetic potential for the yield is also low. Therefore, the major concern of chickpea breeders is how to increase genetic potential for yield. The increased genetic potential in cereal crops has not come from an increase in dry matter, but rather from a progressive increase in harvest index (van Dobben, 1962; Duncan *et al.*, 1978; Austin *et al.*, 1980; Sinha *et al.*, 1981). This is not the case in chickpea because, with few exceptions, the biomass is low. If the biomass is low, little can be achieved by better partitioning.

Singh *et al.* (1983) reported correlation matrix involving evaluation of data on 3269 kabuli chickpea accessions grown at Tel Hadya, Syria. Correlation matrix indicated strong positive associations of seed yield with biological yield, seed weight and, to a lesser extent, with plant height. The relationships of biomass with other characters are shown in Table 2. It is clear that the biomass had the strongest correlation (r = 0.80) with seed yield. It was correlated with plant height. Thus, the taller plant may contribute towards the increased biomass and through it to increased yield.

We have collected large volume of data at ICARDA to prove that the higher the biological yield the higher the seed yield. For example, the results of an CIYT-WMR-86 trial are shown in Table 3. Two conclusions can be drawn from this Table. First, high biomass produces high yield. The seed yield is limited by biomass production

Table 2. Relationships of biomass with other characters on 3269 kabuli chickpea germplasm lines grown at Tel Hadya, Syria, 1979/80.

	DAF	HGT	P/P	BYLD	SYLD	100W
DAF	1.00	0.76**	0.40	0.41**	0.40**	0.37**
HGT		1.00	0.23**	0.50**	0.47**	0.49**
P/P			1.00	0.10**	0.20**	-0.17**
BYLD				1.00	0.80**	0.60**
SYLD					1.00	0.41**
100W						1.00

** Significant at $p \geq 0.01$
DAF = Day after flowering, HGT = Plant height; P/P Pods per plant, BYLD = Biological yield; SYLD = Seed yield, 100W = 100-seed weight.

Table 3. Mean biological yield (BY) and seed yield (SY) (kg/ha) of entries included in the Chikpea International Yield Trial-Winter-Mediterranean Region at Tel Hadya (Syria) and Terbol (Lebanon), 1985/86.

Entry FLIP No.	Tel Hadya		Terbol	
	BY	SY	BY	SY
81-293C	4659	2146	6460	3111
82-101C	4794	2056	6317	2984
82-115C	5060	2144	6286	2952
82-121C	4833	2050	6873	2682
82-127C	4944	2229	6143	3047
82-128C	4357	1971	6698	3242
82-138C	4810	2018	6333	2988
82-154C	4333	1789	6571	3075
82-161C	3973	1707	6587	2865
82-169C	4775	2008	6714	3134
82-172C	4267	1763	6365	2769
82-186C	4576	2050	6540	2968
82-232C	4786	2094	6190	3019
83- 7C	5087	2094	6556	2968
83- 41C	4849	1996	6746	2841
83- 47C	4767	2275	6492	3130
83- 48C	4886	2282	5778	2829
83- 49C	5187	2135	6222	3003
83- 71C	4579	2098	6270	2880
83- 97C	4068	1682	7460	3059
83- 98C	4830	2272	6714	3293
ILC 482	4214	2148	6556	3186
ILC 3279	4484	1805	6397	2833
FLIP 82-150C	3203	1962	6857	3222
Mean	4597	2036	6505	3003
CV (%)	10	10	6	8
SE (±)	242	111	202	127
LSD (5%)	684	313	569	359
r	0.60**		0.26	

** Significant at $p \geq 0.1$

which was in this case around 7 t/ha. If we need a seed yield in excess of 5 t/ha, we need to have biological yield in excess of 12 t/ha. Second, better partitioning between seed and straw yield will be required for increased yield. Various ways could be employed to increase the total biomass per hectare. First, one should attempt to produce taller genotypes. Second, one might succeed in increasing biomass by interspecific hybridization as has been demonstrated in some crops (Frey, 1983). Third, if the tall plants are tailored to be more upright, then by increasing the plant population, one may increase the total biomass and ultimately yield.

Input responsive cultivars

Cereal breeders have made significant advances through breeding cultivars responsive to fertilizer and irrigation. Chickpea breeders have concentrated in the development of germplasm suited to infertile and dry land agriculture. As a result, current varieties perform poorly under high input conditions. Now farmers have more fertilizer and/or water at their command to invest in agriculture for higher return. Lack of input responsive and high yielding chickpeas have two adverse effects. Firstly, chickpea cultivation has been on continuous decline in the developed world, such as Europe. Second, chickpea has been relegated to marginal lands in the developing world, such as India. Therefore, to make chickpea more competitive, it is essential to develop fertilizer, especially phosphate, and irrigation responsive cultivars.

Fertilizer responsive cultivars

At ICRISAT, 1000 germplasm lines were screened for response to fertilizer, but none were identified responsive (Singh, 1987). In a collaborative project between the University of Hohenheim, Stuttgart, West Germany and ICARDA a graduate student evaluated 50 germplasm lines for phosphate uptake in the greenhouse at Stuttgart. He selected four efficient and four inefficient chickpea genotypes and crossed them in diallel fashion. A study of the F_1, F_2, F_3 generations and parents is underway in a phosphate deficient field at Tel Hadya Farm, Syria.

Irrigation responsive cultivars

Generally, kabuli chickpea is grown with supplemental irrigation in the Indian subcontinet, The Nile Valley, Mexico, and a small area in the Mediterranean region.

In order to develop irrigation responsive cultivars at ICARDA 151 genotypes were compared under rainfed conditions and with supplemental irrigation. For supplemental irrigation, three irrigations were added during the 1985/86 season as scheduled by daily water balance computations of rainfall and pan evaporation. The total amount of water including rainfall and irrigation applied was 585 mm. All genotypes except four responded to supplemental irrigation. The 48 most responsive lines were chosen for screening in the following season.

Two trials, each comprising 24 genotypes, were grown rainfed and with supplemental irrigation during the winter season of 1986/87 at Tel Hadya. A total of 495 mm of water was applied which included rainfall and

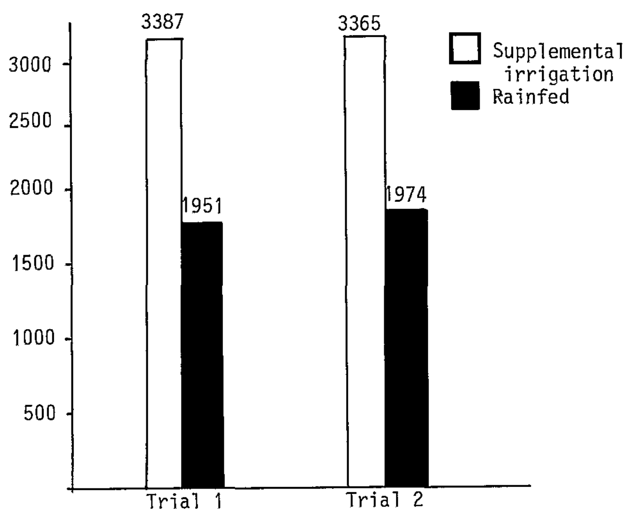

Fig. 2. Mean yield of 24 entries of winter-sown chickpea grown rainfed and with supplemental irrigation at Tel Hadya, Syria, 1986/87.
Source: Unpublished results from K.B. Singh and E. Perrier.

irrigation. The seed yield increased by 74 and 70 percent in trial 1 and trial 2, respectively (Fig. 2) with supplemental irrigation. Most genotypes produced more than 3 t seed/ha with irrigation and less than 2 t/ha without irrigation.

Screening for two years has helped in identifying lines responsive to supplemental irrigation. The performance of five lines is shown in Table 4. Lines which responded to irrigation were average to poor yielders. However, lines which produced high yield under rainfed conditions also gave a substantial increase in yield on irrigation. This study did help in identifying some lines which were high yielding and also high in response . For example, ILC 237 produced the highest yield (4487 kg/ha) when irrigated and high yield (2490 kg/ha) when grown rainfed. For confirmation these experiments were repeated during 1987/88. We hope that by the end of third season, we would have developed a screening technique for irrigation response for its use in breeding chickpeas.

Plant ideotype

Much has been written about plant ideotype (Bahl and Jain, 1977; Byth *et al.*, 1980; Muehlbauer and Singh, 1987; Singh, 1987; Khanna-Chopra and Sinha, 1987), but with little result. Perhaps there is nothing like a universal ideotype. Different situations may require different plant types.

In the past, tall type, double pods per peduncle or miltiseeds per pod were some of the plant types considered ideal. While these types need further investigation, some of the variation found in the breeding plot at

Table 4. Mean seed yield (kg/ha) of five most responsive lines to irrigation and five highest yielding lines under rainfed conditions at Tel Hadya, Syria.

Genotype	1985/86				1986/87				Mean			
	Rainfed	Irrigated	Increase		Rainfed	Irrigated	Increase		Rainfed	Irrigated	Increase	
			kg	%			kg	%			kg	%
Most responsive lines to irrigation												
ILC 202	1048	2152	1104	105	1333	2825	1492	112	1191	2489	1298	109
FLIP 83- 53C	1413	2786	1373	97	1788	3476	1688	94	1601	3131	1530	96
FLIP 83- 69C	1254	2452	1198	96	1683	3153	1470	87	1469	2803	1334	91
FLIP 83- 71C	1310	2556	1246	95	1852	3333	1481	80	1581	2945	1364	86
ILC 142	2111	3690	1579	75	1757	3434	1677	95	1934	3562	1628	84
Highest yielding lines under rainfed conditions												
ILC 1272	3127	3254	127	4	2265	4275	2010	89	2696	3765	1069	40
ILC 100	2437	2660	223	9	2582	2947	1365	53	2510	3304	794	32
ILC 613	2556	2754	198	8	2434	3704	1270	52	2495	3229	800	32
ILC 1929	2754	3175	421	15	2095	3397	1302	62	2425	3286	861	36
ILC 136	2317	3151	834	36	2529	3757	1228	49	2423	3454	1031	79

Source: Unpublished results fron K.B. Singh and E. Perrier.

ICARDA, such as tree type, extra long podding branch with tall stature, multipinnate leaf type need attention (Fig. 3).

Plant population study in relation to plant ideotype may contribute toward high yield. Saxena (1980) reported that as the plant population was increased, there was a corresponding increase in seed yield. But even at the highest plant population level (71.7 plants/m^2), the seed yield was moderate (3041 kg/ha). However, it is concluded that higher plant density is required for high yield and that a new plant type suited for high plant density may be bred.

Photoperiod

Chickpea is a quantitative long day plant (van der Maesen, 1972). Several studies have been reported suggesting that time to flower is reduced under long day length (Khan, 1967; Pandey *et al.,* 1977; Rzhanova and Salykova, 1972; Sandhu and Hodges, 1971; Sethi *et al.,* 1981, van der Maesen, 1972). Singh *et al.,* (1983) suggested a reduction in photoperiod sensitivity in chickpea for wider adoption. They found that when chickpea is grown in the off-season site Terbol, Lebanon at 34°N at an altitude of 980 m from July to October on reducing day length, photoperiod, sensitive lines fail to mature. The F_3 and F_7 generations are grown in the off-season and plants are selected for reduced photoperiod sensitivity. The hypothesis that selected lines are widely adapted is yet to be tested.

There is a need for more research on photoperiodism, particularly on the role of sensitivity to photoperiod in adaptation. CIMMYT's Wheat Program produces less photoperiod sensitive lines and have found them performing well under diverse conditions (Raja Ram, personal communication).

Protein content

Protein content in chickpea is amongst the lowest in pulse group. We evaluated 3263 germplasm accessions for protein content during 1980. The mean protein content in the kabuli germplasm accessions was 20.1 percent with a range of 16.0 to 24.8. Six lines; namely ILC 183, ILC 623, ILC 636, ILC 1158, ILC 1370, and ILC 1991; had more than 24 percent protein content. Lines with a high protein content are low yielding. Most released cultivars have protein contents between 18 and 20 percent.

Fortunately, we have bred by accident three lines, namely FLIP 84-22C, FLIP 84-46C and FLIP 84-49C, which have protein content more than 25 percent. We are in the process of confirming the protein content in these lines. With 25 percent protein content, the crop could also become a good source of cattle feed.

Germplasm

It is now generally agreed that a broad genetic base, as suggested by Vavilov (1926), is essential for crop improvement through plant breeding. The two international centres, International Crops Research Institute for Semi- Arid Tropics (ICRISAT), India and the International Center for Agricultural Research in the Dry Area (ICARDA), Syria, are actively engaged in chickpea genetic resources (Malhotra *et al.,* 1987).

Fortunately, much of the genetic resources in chickpea are still preserverd, but they are in danger of being lost because new cultivars have begun to replace the land races. Though ICRISAT maintains 14,360 accessions and ICARDA 5926 accessions (Malhotra *et al.,* 1987), these do not represent the complete genetic variability in existance. Therefore, it is advisable to collect germplasm before they are are lost for ever.

Van der Maesen (1987) reported 42 wild *Cicer* species, but only 14 are in the gene bank at ICRISAT. Sources of resistance to *Heterodera ciceri* and *Callosobruchus chinensis* were found only in collections of wild species emphasizing the importance of wild species and need for collection on priority.

There has been considerable emphasis on evaluation of germplasm and ICARDA has published a catalog (Singh *et al.,* 1983) and ICRISAT is in the process of publishing a catalog. Despite this and other efforts in evaluation, there is a need for additional evaluation. Whatever genetic variability has been found, they have not been exploited by breeders. The utilization of available genetic resources in chickpea has been weak. In particular, wild species have not been utilized for genetic improvement. Frey (1983) demonstrated that wild species can also contribute toward increased yield.

Induced mutation

The role of induced mutation has been a subject of controversy among the plant breeders. Some believe that induced mutations are shortcut solutions to various plant breeding problems. Brock (1976) calculated on the basis of records of released mutant cultivars that the average time which elapsed from the end of the mutagenic treatment to the release of the mutant cultivar was 8.9 years for cultivars which were direct multiplications of mutants as compared with 18.0 years for cultivars arising from crossing programmes. Granted time taken for the development of cultivars through mutation may be less as com-

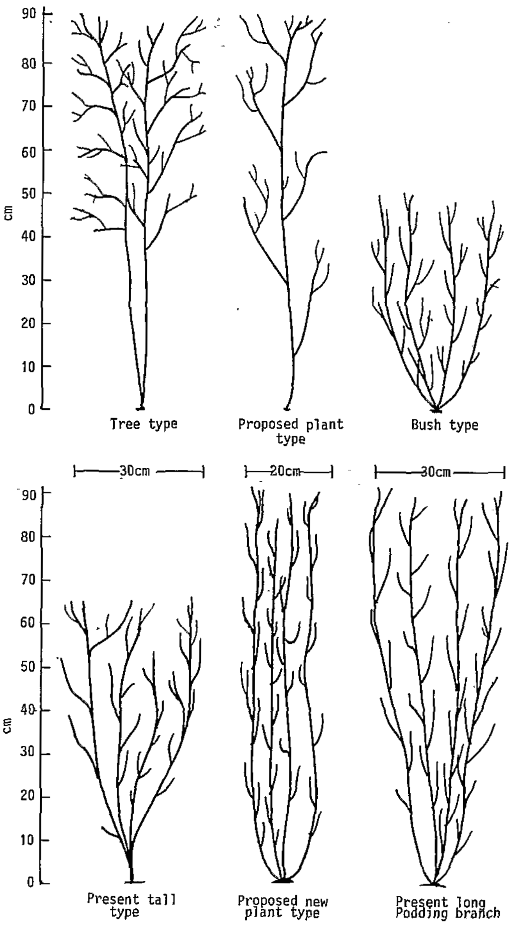

Fig. 3. Different plant ideotypes in chickpea.

pared to those through hybridization, mutation breeding can not substitute the normal breeding method. Singh (1987) recently compiled information on varietal development through various breeding methods and found that 101 cultivars were developed through introduction, 47 through hybridization and only three through mutation in chickpea. Obviously, mutation has not been a potent method for varietal development.

However, there are many useful traits present in other crops but absent in chickpea; for example cytoplasmic-genetic male sterility, determinate plant type, tall erect and compact plant type, multiple pods per peduncle, multiple seeds (3-6) per pod, and resistance to cyst nematode. Induced mutation can be used to create these and other useful characters for use in plant breeding programme. A graduate student at ICARDA has obtained a plant which is 25 percent taller than the tallest germplasm line at ICARDA. Dr. Paola Crino (personal communication) has discovered a plant from M_2 population resistant to race 6 of *Ascochyta rabiei*. Clearly, induced mutation is recommended to create a new genetic variability missing in the germplasm collection.

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