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Consideration of chickpea plant ideotypes for spring and winter sowing

F. SACCARDO*
F. CALCAGNO**
*CATTEDRA DI MIGLIORAMENTO GENETICO DELLE PIANTE AGRARIE
UNIVERSITA DEGLI STUDI DI NAPOLI, PORTICI, ITALY
**STAZIONE SPERIMENTALE DI GRANICOLTURA PER
LA SICILIA, CALTIGIRONE, CATANIA, ITALY

SUMMARY - Chickpea is commonly grown as spring sown crop in the Mediterranean basin. Yield significantly increases when the sowing date of chickpea is shifted from spring to winter time. Two different ideotypes were identified suitable for the winter and spring sown crops under Italian conditions. The winter type has to be resistant to ascochyta blight, cold tolerant, with a long vegetative cycle and erect habit, and bearing pods on upper parts of the branches to facilitate mechanical harvesting. The ideotype for spring sowing was the one characterized by the Italian landraces and has a short vegetative cycle, a good adaptability to both southern and central Italian environments, high yield and good grain quality. After agronomical trials, carried out in different locations for several years, two lines were selected for winter sowing ("Califfo" and "Sultano") and another two for spring sowing ("Principe" and "Calia"), and proposed for release as new cultivars.

RESUME - "Considérations sur les idéotypes de plantes de pois chiche pour les semis de printemps et d'hiver". Le pois chiche est traditionnellement semé au printemps dans le bassin méditerranéen. Le rendement augmente fortement quand la date de semis est déplacée vers l'hiver. On a identifié deux idéotypes différents adaptés soit au semis d'hiver, soit au semis de printemps dans les conditions de l'Italie. Le type hiver doit être résistant à l'anthracnose, tolérant au froid, il doit avoir une longue phase végétative, un port érigé et porter des gousses sur le sommet des ramifications pour faciliter la récolte mécanique. Le type printemps est représenté par les populations locales italiennes, avec un cycle court, une bonne adaptation aux conditions d'environnement du sud et du centre de l'Italie, une bonne productivité et des graines de qualité. A la suite d'essais agronomiques, conduits en différents lieux pendant plusieurs années, on a sélectionné et proposé à l'inscription deux lignées pour le semis d'hiver ("Califfo" et "Sultano") et deux autres pour le semis de printemps ("Principe" et "Calia").

Introduction

Chickpea area is very limited in Italy. In the last 30 years, the land devoted to chickpea crop has decreased considerably, from 110,000 ha in 1950 to 11,000 ha in 1984. Several factors have caused this decrease:

a) agronomic, economic and social standards have made cropping system less dependent on pulses;

b) the lack of cultivars adapted to southern climates, characterized by abundant rainfall in autumn and winter but insufficient precipitation in spring and early summer;

c) high sensitivity to photoperiod and temperature;

d) the susceptibity to several parasites, mainly *Ascochyta rabiei,* causing severe damage to the crop.

In southern Europe, chickpeas are almost exclusively cultivated as early spring crop (sowing in the end of February or beginning of March and harvesting in June), since at this time the temperatures start rising and the winter rains end. The crop length varies from three to four months and the growth rate is determined by the temperatures and the water stress of early summer. The shift of the sowing date of chickpea to November or early December (winter sowing) allows the reaching of physiological maturity in June. In these conditions the plant profits from better moisture conditions, resulting in a better vegetative and reproductive development.

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In order to assess the influence of the sowing date on the yield performance of chickpea, experiments were started during the 1974-75 season, in the framework of the Arid Lands Agricultural Development Program, Ford Foundation, Beirut, and later continued by ICARDA (Saxena, 1980; Hawtin and Singh, 1984). Saxena (1980) and Singh *et al.* (1984) have demonstrated a higher yield potential for the winter sown crop than the spring one. The results of these studies showes that (1) chickpea genotypes could survive winter conditions even when the lowest temperature fall to -12°C; (2) when the winter sown crop was protected from Ascochyta blight by spraying fungicides yield increased up to 100% in comparison with the spring sown; (3) Ascochyta blight resistant lines had a mean yield twofold higher than the mean yield of the susceptible ones; (4) the mean yield of the winter trials in many locations was 3.0 t/ha, the highest value being 4.2 t/ha.

The present study attempts to identify specific ideotypes for chickpeas adapted to winter sowing and spring sowing.

Strategies for selecting chickpea ideotypes adaptable to italian conditions

Genetic improvement strategy adopted for developing chickpea lines suited for winter and spring sowing in Italy is shown in Fig. 1. It is based round the evaluation of exotic and local germplasm, local land races and cross-breeding.

Evaluation of germplasm

The utilization of international and local germplasm collections is of paramount importance for chickpea breeding since a wide variability for morphological and physiological traits as well as yield components and disease resistance has been reported (Singh and Malhotra, 1984). Nevertheless, it should be emphasized that cross-ability between cultivated chickpeas and their wild relatives is limited, restricting the availability of utilizable genetic variability (Singh, 1986).

At ENEA, Rome and Stazione Sperimentale di Granicoltura per la Sicilia, Caltagirone-Catania, genetic and agronomic evaluation of 835 lines of chickpea coming from germplasm collection of ICARDA, Aleppo, Syria, and CNR Institute of Germplasm, Bari, Italy has been carried out from 1981 to 1985. All the lines were evaluated in winter and spring sowing at two sites, Tarquinia, Viterbo, and Caltagirone, Catania. Among these lines, 21 genotypes were identified to be high yielding, cold tolerant and resistant to *Ascochyta* blight. Particularly, 5 ICARDA accessions (ILC 484, 482, 515, 72 and 3279) have been selected for winter sowing. Their agronomical and physiological characters have been reported in Table 1. The lines ILC 3279 and ILC 72 have been the genetic material from which the new Italian winter cultivars "Sultano" (ILC 3279) and "Califfo" (ILC 72) have been selected (Saccardo *et al.*, 1987).

Selection in the Italian landraces

Some Italian landraces, mainly collected in different parts of southern Italy, were evaluated to select material better adapted to winter and spring sowing conditions. Selections have been carried out for agronomical and physiological traits. All this material has shown a good adaptability for spring sowing and two of them (Ecotype 1 and 2) have been selected as new spring varieties, called "Calia" and "Principe" (Saccardo *et al.*, 1987).

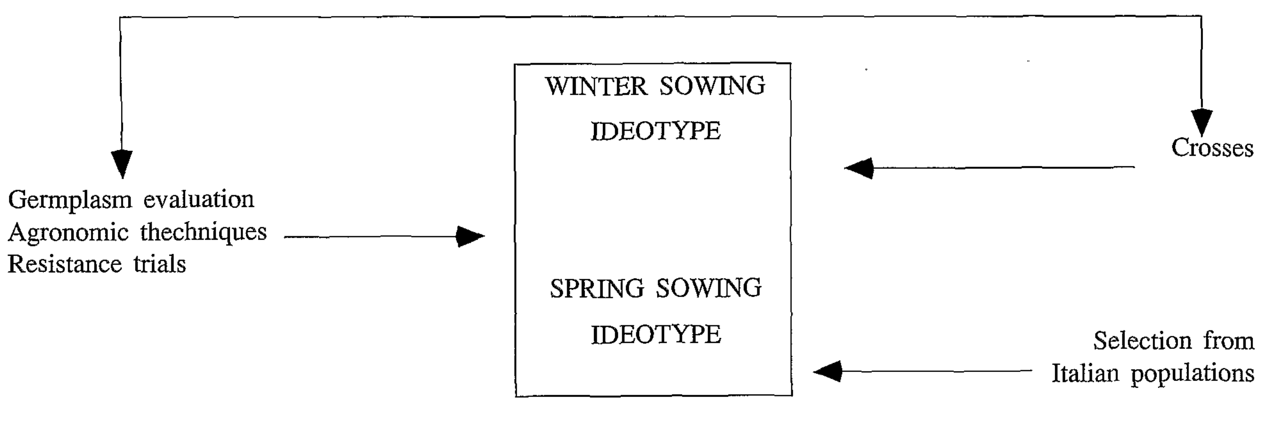

Fig. 1. Genetic improvement strategies for selecting chickpea varieties adapted to new cropping techniques.

Table 1. Agronomic and morpho-physiological characters of kabuli chickpea genotypes selected for winter and spring sowing in 3 years of experiments (1983-1985) carried out in 8 different locations in central and southern Italy.

Genotypes	Origin	Sowing time	Plant type	Plant height (g)	Seeds/ plant	100-seed weight (g)	Stress response	
							Cold	Ascochyta blight
ILC 484	Turkey	Winter	Semi-erect	47.7	24.6	28.19	T	R
ILC 482	Turkey	Winter	Semi-erect	49.3	24.0	31.92	T	R
ILC 515	Turkey	Winter	Erect	47.1	22.5	25.82	T	R
ILC 72	Spain	Winter	Erect	67.2	20.7	28.93	T	R
ILC 3279	USSR	Winter	Erect	64.2	20.4	27.74	T	R
Ecotype-1	Italy	Spring	Semi-prostrate	48.8	24.4	31.92	S	S
Ecotype-2	Italy	Spring	Semi-prostrate	48.1	18.6	44.65	S	S

R = Resistant; T = Tolerant; S = Susceptible.

Table 2. Genetic variability for agronomic and morpho-physiological characters of F_5 breeding lines of *Cicer arietinum* L. selected in Tarquinia (1) and Caltagirone (2) in comparison to Italian ecotypes.

Material	Plant (cm)		Pod bearing height		Pod per plant		Resistance to ascochyta blight	
	1	2	1	2	1	2	1	2
F_5 lines[a]	35-76	50-78	31-48	25-52	67-162	19-52	R	R
Italian ecotypes	47	42	24	28	51	18	S	S

[a] Lines derived from crosses between Italian ecotypes and ICARDA germplasm.

Crossbreeding program

In order to achieve a wider genetic variability, a selection program was started in 1983 using segregating populations from ICARDA and ENEA. Selected F_3-F_7 progenies were analysed for morphological and agronomical traits as well as ascochyta blight and cold resistance either in Tarquinia, Viterbo or in Caltagirone, Catania. A good range of variability was found and 84 F_5 lines were selected in both localities for their superior agronomic characters such as yield performance, erect growth habit, cold tolerance and ascochyta blight resistance, over the control checks (Table 2).

Specific plant characters needed for winter and spring sowing

Crop duration

A long crop duration is essential for winter cultivars since it allows a more vigorous vegetative and reproductive development with a consequent increase in productivity. In winter and spring sowing, 25 genotypes of different origins including 2 Italian ecotypes were agronomically evaluated. Winter genotypes with a longer biological cycle yielded 21% more than the yield in spring sowing and the productivity was positively correlated with the height of the plant (Calcagno *et al.*, 1987). However, the relationship of plant height with yield was parabolic. Very early sowing resulted in large increase in height and total biomass but the grain yield decreased. Two genotypes characterized respectively by short ("Calia") and long (ILC 3279) biological cycle (Fig. 2) have been further analysed at different sowing dates. Accession ILC 3279 gave maximum grain yield when the sowing date was advanced to early December, while Calia expressed the best potential in spring sowing.

Plant architecture

In the germplasm collection, two different plant architectures have been identified: tall and erect type and the prostrate one. The first is more adaptable to winter sow-

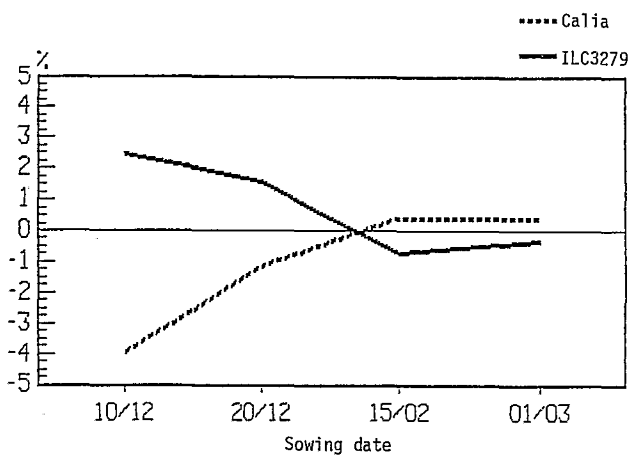

Fig. 2. Grain yield variation (% of the mean yield value) of two genotypes characterized by short (Calia) and long (ILC 3279) bilological cycle in winter and spring sowing.

ing. The placement of pods on upper parts of the branches makes the mechanical harvesting easier. Plant density could be increased to improve the biological yield. Experiments conducted on plant density utilizing chickpea lines characterized by different plant architectures (semi-prostrate, semierect and erect) showed that it is possible to increase the density to 80 plants/m^2 using the erect types, whereas a density of 24 plants/m^2 was optimum for prostrate types (Table 3). Moreover, the erect plants can intercept a larger portion of solar radiation, successfully compete, with weeds and use the available moisture more efficiently.

The smaller, semi-prostrate plants with several lateral branches are instead more adaptable to spring sowing.

Table 3. Recommended plant density for chickpea lines of different plant-types.

Plant-type	Plants/m^2	Distance between the rows (cm)	Distance within the rows (cm)
Semi-prostrate	24	40	10
Semi-erect	40	25	10
Erect	80	12	10

Inter-plant competition ability

Low yield, low harvest index and low yield stability, which is a characteristic of pulses, can be attributed to high inter-plant and intra-plant competition (Monti, 1987).

The effects of reduced leaf area on competitiveness has been clearly demonstrated in peas, where the genotypes with normal leaf type was grown in mixture for 4 generations with recessive lines for *af*, *st* and *tl* genes with drastically reduced leaf area: the afila type, with the most reduced leaf area, disappeared rapidly when grown with the other types (Leone, 1984), while when grown pure its seed yield was comparable to that of the normal leaf type.

The intra-plant competition in a crop is particularly severe when light intensity in the conopy, water and nutrients in the soil and biotic stresses (pests, diseases, cold) are limiting the growth. A pure cropping is efficient only when the inter-plant competition is reduced in such a way that only a limited plant to plant variation is present.

In order to select winter chickpea genotypes, with reduced interplant competition, germplasm has been tested in microplots at plant densities used for the normal cultivation; the seed yield of 9 plants from three replications, harvested in the central part of the plot, where the inter-plant competitiveness is strong, have been compared with the seed yield of 9 plants harvested in the external rows, where the plants are subjected to a weak inter-plant competition. Differences in seed yield per plant have been found among 26 selected advanced chickpea lines, according to the position of the plant in the plot; the seed yield per plant ranged between 18 and 24 g for the plants grown in the central part of the plot, and between 22 to 31 g for those grown in the external rows. The ratio of the seed yield of the central and the external plants, as estimate of the inter-plant competitiveness, ranged between 59 and 107% (Table 4); higher the ratio, lesser was the inter-plant competition. Differences in the inter-plant competition ability among chickpea genotypes have also been found in winter sowing experiments. Erect types showed increasing seed yield with increasing density upto 40 plants/m^2 while the semi-prostrate type gave the highest yield at 25 plants/m^2 (Fig. 3) (Calcagno *et al.*, 1987).

Table 4. Seed yield mean values of chickpea plants from advanced breeding lines grouped on the basis of the competition between central and external rows.

Competitiveness	Number of lines analysed	Seed yield (g) S.E.	H.I. S.E.	Seed yield (g)		Center Edge %
				Center S.E.	Edge S.E.	
High	11	24.24 ± 1.08	0.38 ± 0.01	18.35 ± 1.08	31.20 ± 1.56	59
Medium	7	23.62 ± 1.09	0.39 ± 0.02	21.37 ± 1.18	25.85 ± 1.58	83
Low	8	22.24 ± 1.32	0.38 ± 0.01	24.34 ± 1.91	22.70 ± 1.26	107

Cold tolerance

The winter sowing of chickpea in central and southern Italy is only possible if cold tolerant cultivars are available. Wind and frost tolerance are important components of adaptation of the crop to winter and to high altitudes sowing. Studies on cold tolerance in chickpea (Singh *et al.*, 1981; Singh *et al.*, 1984), have shown that inheritance of cold tolerance is under the control of dominat polygenes (Singh *et al.*, 1984). In Italy chickpea lines selected from previous breeding programs have been screened in 1986 for cold tolerance in the open field, by sowing them in November and December at Torre Lama, Salerno, a locality where the temperature normally falls below zero during January and February (-10 to -11°C for 1 week in 1986). A 0-5 scale (0 = 100% of plants mortality; 5 = 100% of survival plants) was used for the

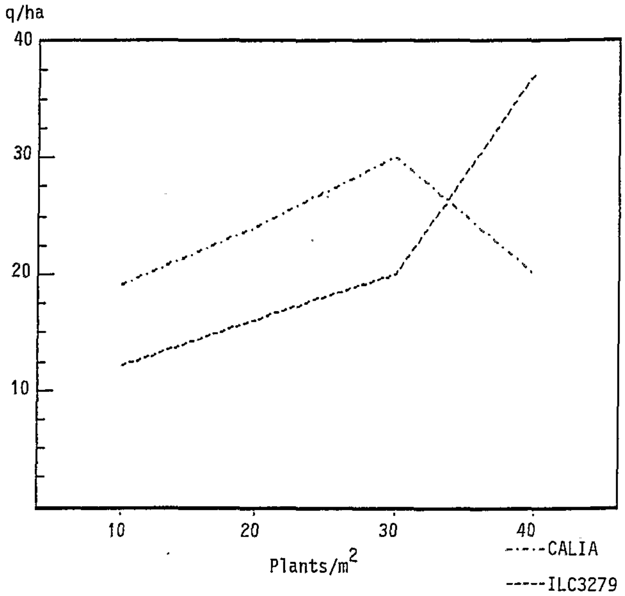

Fig. 3. Yield of chickpea varieties characterized by erect (ILC3279) and semi-prostrate types (Calia) as affected by plant population.

screening. 27 lines were identified as cold tolerant, giving an acceptable yield (1.93 t/ha) and with a plant survival rate of (50-70%) which was higher than that of the Italian ecotypes (Table 5). A new technique has been recently set up to screen rapidly large germplasm collection. Plantlets at 10-15 leaves stage have been exposed to different temperature cycles (from 4°C to -5°C) for 72 hours in criothermostate apparatus. The results, obtained by comparing tolerant and susceptible lines, have been consistent with the data obtained in the open field.

Table 5. Evaluation for cold tolerance of chickpea germplasm tested at Torre Lama, Salerno in winter 1986-87.

Genotype	Grain yield (t/ha)	H.I.	Survival rate
27 advanced selections[a]	1.92	0.39	50 to 70
Italian ecotypes	0.30	0.25	5 to 20

a/ F_5-F_6 lines derived from crosses between Italian ecotypes and ICARDA germplasm; cold tolerant lines were selected each year in cold stress conditions.

Drought tolerance

Chickpeas sown in spring have higher photorespiration rate due to high temperature during the growth period and the high insolation mainly during the pod filling time. These conditions influence negatively the growth and consequently the yield capacity. However, it is possible to select genotypes adaptable to spring sowing since genetic variability for morphological and physiological traits has been found. High-yielding genotypes belonging to Italian ecotypes have been selected, characterized by earliness, a higher number of fertile branches at the basal part of the plant and a good grain quality.

Disease resistance

Ascochyta blight represents the most serious disease affecting winter chickpea crops, especially in West Asia and Mediterranean regions. The pathogen can be controlled by fungicide spray, but because of expenses and toxicity of fungicides, plant resistance should be considered one of the best disease control strategies. Sources of resistance and their genetic control have been known for fifty years, as reported by Nene and Reddy (1986) and by Crino in this meeting.

Experiments carried out in Sicily demonstrated that among 25 genotypes coming from ICARDA germplasm and tested in open field in winter sowing, five were resistant to ascochyta blight, where the others were susceptible (Table 6). The resistance of 5 lines selected in open field (ILC 484, 3279, 72, 482 and 515) has been confirmed in greenhouse by artificial inoculations with different Italian isolates of *A. rabiei* (Porta Puglia *et al.*, 1987).

Fusarium wilt, which is a serious disease of chickpea in Spain and other Mediterranean countries, could also be a limiting factor for the spring crop in Italy.

Proposed ideotypes

Work for the last 5 years in different areas in Italy has helped in identification of three ideoptypes (Spring, Winter-1, and Winter-2) as illustrated in Fig. 4 and described in Table 7. The 'Spring' and 'Winter-1' types have been well characterized. Selection is currently in progress to obtain a plant taller than the erect type with few lateral branches and apical pod position to meet the ideotype requirement for 'Winter-2' type. This ideotype should permit an increase of plants density and an improvement of the biological yield per unit area. The 'Spring' and 'Winter-1' ideotypes may need a population density of 24 and 40 plants/m^2 as against 80 plants/m^2 for 'Winter-2'. The corresponding yield expectation are 1.6-1.8, 2.4-

Table 6. Evaluation of *Ascochyta rabiei* resistance of 25 chickpea genotypes in winter sowing, Caltagirone, 1984.

Genotype	Reaction to ascochyta blight	Average yield in ascochyta free field	Average yield in ascochyta infected field	Plot damage by ascochyta blight (%)	Yield loss %
ILC 484, 3279, 72, 482 and 515	R	2.045	2.045	0	0
Principe, ILC 3256, Calia	S	1.537	1.172	25	21.30
ILC 451, 1934, FLIP 81-163, ILC 1932, 112, 237.	S	1.687	1.081	50	31.40
ILC 295, FLIP 80-5, ILC 1922, 263, FLIP 81-65 ILC 1931, FLIP 81-54, 81-32, 81-45.	S	1.814	9.66	50	41.50
ILC 1529 and 5003	S	1.757	5.02	75	>50

R = Resistant; S = Suceptible

Table 7. Winter and spring chickpea ideotypes for Italian conditions.

Main traits	Spring type	Winter type 1	Winter type 2
Morphological			
Plant height	30-40 cm	60-70 cm	70-80 cm
Plant type	Semi-prostrate	Semi-erect	Erect
Lodging	Resistant	Resistant	Resistant
Pod shattering	Resistant	Resistant	Resistant
Pod bearing	Lower part	Middle part	Upper part
Branching	High	High	Reduced
Physiological			
Grain yield/plant	6.5-7.0 g	6.0-6.5 g	4.5-5.0 g
Seed number/plant	16-18	24.26	36.40
Days to maturity	100-120	150-180	170-180
Inter-plant competition	High	Medium	Low
Harvest index	High	High	High
Stress Resistance			
Ascochyta blight	Resistant	Resistant	Resistant
Cold	Not important	Tolerant	Tolerant
Drought	Tolerant	Not important	Not important

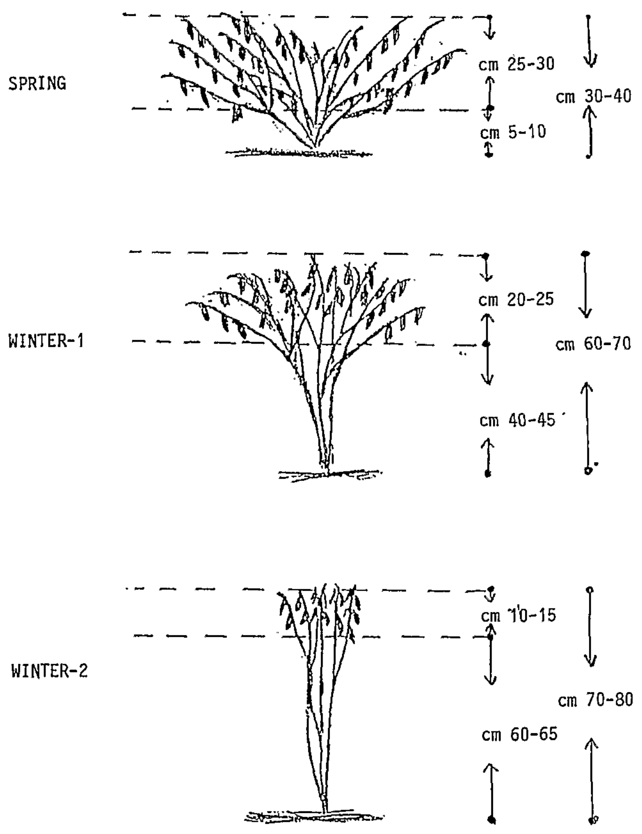

Fig. 4. Chickpea ideotypes for spring and winter sowing in Italian conditions.

2.6 and 3.6-4.0 t/ha, respectively from the three ideotypes.

Development of cultivars as per the proposed ideotypes could permit increase in area devoted to chickpea in Italy, particularly if winter types are adopted. Two varieties, "Sultano" and "Califfo", adapted for winter sowing have produced more than 2.5 t/ha which is a good yield level when compared to the yield of 1.0 t/ha from the traditional spring cultivars. In some localities, however, spring sowing will continue to remain the only possibility and, for this purpose, the varieties "Principe" and "Calia", corresponding to spring ideotype, have been selected. The good grain quality of these two spring genotypes makes them very suitable for human consumption whereas the winter cultivars could be used for animal feeding as an alternative to soyabean in the central and southern Italy. Studies, are, however, needed to develop a better knowledge of the nutritive values of chickpea as well as to develop new food products through application of appropriate processing technology.

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