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MUTATION BREEDING OF DURUM WHEAT

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SUMMARY

A comprehensive programme on experimental mutagenesis was started in 1956 for both genetic research and mutation breeding at the Nuclear Center. Remarkable efforts were produced on durum wheat over the past 20 years and a lot of knowledge was gained on several aspects of this crop: radiobiology, mutagenesis, cytology and cytogenetics, genetics and breeding.
This review concern: radiogenetical studies, isolation of useful mutations, agronomic evaluation of mutant lines and use of mutations in hybridization programs.
Details are given on the genetic contribution of mutagenesis to the evolution of new cultivars in durums and on the economic evaluation of the cultivars obtained by mutation breeding.
An economic return on mutation breeding of durum wheat is attempted.

1. INTRODUCTION

Durum wheat is considered a crop of semi-arid climates; it is grown mostly in Southern Europe, North America, North Africa, Near East, USSR and Argentina.
The genetical studies in this crop were almost neglected in the first half of the century: and the yield of durum was substantially lower than in bread wheat towards which the major efforts were devoted. In view of the economic importance of durum wheat in Italy and in the Mediterranean Area a programme on experimental mutagenesis in this crop was started by D'Amato and G.T. Scarascia in 1956, for both fundamental genetic research and mutation breeding.
Many efforts have been produced at the Agriculture Laboratory of Casaccia Nuclear Center, CNEN, during the past 20 years on several aspects in this crop: radiobiology, mutagenesis, cytology and cytogenetic, genetics and breeding.
In the meantime, in the world, remarkable improvement has been obtained in durum wheat: considered until 15 years ago a poor crop for poor regions, the new durum varieties are now competitive for yielding ability with the best bread wheat varieties. The variety spectrum has changed rapidly and deeply by using different breeding tecniques: introduction, intervarietal-crosses, interspecific and intergeneric

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hybridizations, mutagenesis. All these techniques were applied at the Casaccia Center where a rapid development of new plant types was obtained with agronomic results of economic value. The paper is an attempt to evaluate the contribution of mutagenesis on the improvement of durum wheat varieties.

2. RADIOGENETICAL STUDIES

Seeds of several varieties namely: Cappelli, Russello, Grifoni, Capeiti, Aziziah, Garigliano, Appulo, Maliani 8D, LD 357, Patrizio, GA B125, Sincape have been treated both with chemical such as ethyleneimine (EI), diethyl-sulphate (DES) and ethyl-methane-sulphonate (EMS) and physical mutagens as X-rays, fast (Nf) and thermal neutrons (Nth) [1,2,3,4,5]. The relative efficiency [6] of the mutagens was established on the basis of M_1 spike fertility and on M_2 clorophyll mutation frequency. In general the relative efficiency of the mutagens was as follows: $EI < DES \leqslant X < Nf \leqslant EMS \leqslant Nth$ (the range of mutation frequency being from 1 to 24%). For morphological mutations the relative efficiency was slightly different: $EI < X < DES < EMS \leqslant Nth \leqslant Nf$ (the range of mutation frequency being from 1 to 41%). [7,8,9,10,11,12,13]

Knowledge is acquired on the mode of inheritance of induced mutations being mostly monogenic recessive. Nevertheless some mutations namely elymoid, spherococcoid and yellow green behave bifactorial when crossed with other varieties and monofactorial when crossed with the parental variety.

Dominant and monofactorial behaviour was ascertained for the short straw mutation induced in Cappelli (mutant Cp B132) and semidominant, but not definitively monofactorial behaviour, for a mutation affecting kernel size induced in Cappelli (Cp CB 2 mutant).

Several methods of irradiation (acute, chronic, recurrent) at different ontogenetic stages of the plant (such as seeds, gametes) have been applied in order to enhance the frequency of mutations and to overcome the chimaera situation. Results of durum wheat varieties subjected to chronic irradiation for all the life cycle have clearly shown the frequency of mutations is not higher as compared with those of acute seed irradiation [14, 15]. Repeated treatment, one or more times in different generations, has given (as expected in durum, being tetraploid species) a higher mutation frequency up to a doubling of the chlorophyll mutations when the number of exposure was repeated five times. Seed treatment as found by others, leads to a M_1

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chimaeric plant and for this reason a method of gametophyte treatment have been applied. Results obtained in durum wheat and barley gametophyte irradiation have clearly shown the real possibility of overcoming chimaeric situation in the M_1 plants, being heterozigous in all the spikes for the induce mutations [16, 17].

The selection of mutated plants has been carried out by applying screening methods based on visual ispection or using appropriate techniques for the identification of the expected changes on a single plant basis.

In order to establish the efficiency of both mutagens and methods of treatments the rate of chlorophyll mutations has been considered as an index of relative mutagenic efficiency. A positive correlation between the frequency of chlorophyll mutations and the frequency of morphological mutations has been demonstrated both in controlled conditions and in open field [4, 5, 6].

The distinction between qualitative and quantitative characters, even though irrilevant from the genetic point of view, is important for the plant breeder who has to choose the proper selection procedures according to the nature of the traits he is selecting for.

The induction and isolation of a wide array of mutations have been often very helpful to the plant breeder, not only for the increase of the variability [18], but particularly for the change of the inheritance pattern of some characters, such as plant height which is normally under polygenic control. Mutations drastically affecting characters like culm length, kernel weight, number and lenght of internodes, heading time etc. have been induced in durum wheat and handled as simple inherited qualitative traits [7, 11, 19, 20, 21].

The experimental mutagenesis has noticeably contributed to the recognition of durum as unique species. As a matter of fact a great deal of destinguishable morphological types similar to those occurring in nature has been obtained through mutagenic treatments of a limited number of durum wheat varieties. Therefore, it has been possible to argue the principles of the previous botanists who were used to classify simple morphological deviants as different species. The conclusions reached by Mackey [22], now shared by almost all people, points to the grouping of several tetraploid wheat species in only one species: Triticum turgidum. This assumption is well supported by the findings of the mutagenesis work [23]. It is here sufficient to recall the mutants "spherococcoid" and "elymoid" isolated in the

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varieties Azizia and Capeiti. An "elymoid" mutant has been isolated even in Secale at CIMMYT; thus confirming once again the general rule of parallel variations in plants (cfr. Vavilov, 1950).
These findings, reinforce the monophiletic hypothesis on the origin of the genus Triticum from one diploid ancestral species. They also indicate way how to exploit the genetic variation which resides in each species. Triticale (Triticum x Secale) is just a brilliant example of how much fruitful the combination and successive enginering of different genomes can be. The exploitation of mutants with high homeologous pairing due to the absence of the gene(s) Ph on the long arm of chromosome 5B [24, 25] can widen the scope for the introduction of alien variation in durum as well as in bread wheats.

3. ISOLATION OF POTENTIAL USEFUL MUTATIONS

In general, the M_1 plant raised after seed irradiation has been segretated according to the spike-progeny method; less frequentely, the bulk method was applied. After the selection of mutations in M_2 and M_3 generations, great care was taken in the following two or three generations in order to make a preliminary selection of the mutants of possible value and interest for breeding purposes.
Using this technique numerous useful mutations have been identified. They affect characteristics related to the improvement of durum wheat, such as culm-lenght, number of internodes, solid stem, size, numebr and disposition of leaves, lodging resistance, earliness, decreased yellow berry percentage, male sterility and resistance to deseases [26, 27, 28, 29, 30].
The lodging susceptibility and the straw weakness of durum wheat have been a serious problem affecting the yield. Until 1964 no natural sources for culm shortening were available for the breeders in durum wheat.
The induced mutants for short internode and plant height were evaluated for lodging resistance. The plant height reduction of the mutants ranged from 10 to 47 % of the parental variety height. However there is no absolute correlation between short straw and lodging resistance since among the short straw mutants with the same culm-lenght marked differences have been observed. A typical case is represented by two mutant lines from Cappelli: Cp B132 and Cp B2, both 90 cm. height. The former has appreciable resistance, while the latter is as susceptible to lodging as Cappelli, whose culm-lenght is about 130 cm. [19, 27].

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Mutants were isolated for earliness to escape the drought, frequentely occurring in the Mediterranean Area during the ripening time. Theheading time, currentely assumed as a good index correlated with the ripeness, has been taken as a parameter of screening.
Mutations for earliness were obtained by mutagenic treatment from the cv. Cappelli, Garigliano, Russello, Grifoni, Capeiti and LD 357. The earliness obtained in the varieties Cappelli, Garigliano and Grifoni did not exceed 2-3 days while mutants isolated in Capeiti (which is one of the most early variety) were as earlier as 8 days. In these cases the induced mutations are often associated with a shorter culm length, a certain reduction of seed set and grain size. The earlier is the mutant, the higher seems to be the probability that such a mutant beaffected by other kinds of phenotypic changes, either morphological or pigmental, or by a reduction of fertility. However several mutants do occur with unchanged fertility [28, 30]
The early mutants were less frequent than the late ones in all the experiments of mutagenesis so far carried out in durum at Casaccia Center.
Durum wheat is a basic staple food for a great deal of world's population; hence it represents an important source of proteins. Analyses performed for protein content in a number of lines mutated for various morphological characters, as height, heading time etc., obtained from various mutagenic treatments in the cv. Capeiti, revealed that at least 18 lines, out of 173, were characterized by higher protein content ranging from 144 to 166 % of the mother variety. In spite of unfavorable association between protein content and yield a set of seven lines was identified, better than Capeiti, both for protein content (128-152 % more than the control) and yielding ability [31].
Mutagens have been used to induce mutations for desease resistance. Among the 8 short mutant lines tested for bunt resistance (Tilletia triticoides) two mutants Cp B144 from Cappelli and Rs A1 from Russello proved to be more resistant than the controls, whereas Gr A145, a mutant from Grifoni, shows a higher susceptibility [32]. However, the presence of material with a different degree of resistance in the original population used for mutagenesis cannot be ruled out.
Other mutations affecting morphological and physiological characters have been isolated after mutagenic treatment. They concern the absence of ligula [33] (3 mutants from Capeiti and Castelnuovo) and the mutants with yellow green

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leaves (1 from Cappelli and 1 from Capeiti). Though not suitable for direct use, they were considered in cross-breeding programme for a better utilization of light by the canopies.
Awnless and smooth awns mutants, male sterile mutants have been also induced and they might be used for physiological studies and for a practical exploitation of heterosis in durum wheat.

4. AGRONOMIC EVALUATION OF MUTANT LINES

a) In Italy

Having at our disposal a large stock of different mutant lines, apparently endowed with agronomical characteristics, it was possible to undertake a programme aimed at ascertaining the concrete possibility of direct use as a new variety of the best mutants identified in the preliminary trials.
Starting from the M_6 generation, large-scale field trials were first carried out in different region of Central and Southern Italy in order to evaluate the new lines in different agronomic environments [20, 26, 28]. The mutant lines were tested in comparison with mother varieties of durum wheat cultivated in Italy (Capeiti, Patrizio, Camar 7, Sincape 9, Maristella, Ichnusa) and with foreign varieties. Data were collected for heading and maturity time, lodging, number of spike per square meter, grain yield, test weight 1000-grain weight, yellow berry.
For all the agronomical data gathered it was clearly demonstrated that through mutations it was possible to obtain in durum wheat, lines of agronomic value giving a consistent improvement in the performance of this crop. From this extensive evaluation of mutant lines, four mutants, as a new varieties, were registered and released to the farmers.
Two lines from Cappelli (Cp B132 and Cp C48) were released in 1968 and named Castelporziano and Castelfusano respectively. In 1969 the best mutant line derived from the variety Grifoni (GR A145) was released with the name of Casteldelmonte, while in 1970 registration was requested for a line (GA B125) isolated from the variety Garigliano and it was named Castelnuovo.

b) International co-operative trials

Positive results have been also obtained from an International Programme, sponsored by FAO/IAEA [34], for the

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assessment of the practical value of some mutant lines in the Mediterranean and Near East Regions. Multilocation nurseries have been carried out since 1965 and 57 experimental fields, spreaded over 16 countries, have been settled in 4 years of trials. Each field trial included eight mutant lines, two Italian varieties (Cappelli and Capeiti) and two local varieties, chosen by each co-operator.
Useful informations on the genotype-environment interaction were achieved; the highest yields were shown by two mutant lines (GA 125 and GR A145) and by Capeiti variety. From these co-operative trials we could surely infer that for the typical areas of durum wheat: North Africa, Middle East and generally, in the Mediterranean Region, early and lodging-resistant lines are required. Also, it seemed that local varieties could be easily equalled or outyielded by new introductions as shown by the performance of the induced mutant lines.

5. USE OF MUTATIONS IN HYBRIDIZATION PROGRAMS

Crosses between mutants and mother variety, between mutants for the same (or different) trait(s), coming from the same (or different) variety(s); between mutants and other varieties, have been performed at Casaccia Nuclear Center over the past 15 years [27, 35].
The objectives of this program are as follows:
- transfer of beneficial mutations in other genotypes;
- combination in the same genotype of two or more mutations affecting the same character or different characters;
- analysis of the genetical behaviour of the mutations;
- development of new varieties of durum wheat.

Mutants from cultivars Cappelli, Garigliano, Capeiti, Azizia, Grifoni, Russello, Sincape have been largely used in a cross breeding programm aiming at obteining genotypes possessing mutations for reduced plant height and earliness. In general it has been found a good combining ability of the mutants for the more remarkable agronomic traits, namely yielding potential, quality and desease resistance. The genetic effect of mutations for short straw has been shown to be additive either for mutations induced in different varieties, or for different mutations isolated in the same variety as in the case of the mutants Cp B132 and Cp C48, both induced in the cv. Cappelli.
In the segregating generations plants shorter of either parents have been selected. These new types possess both mutations in homosygote condition. Furthermore, such con-

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dition implies other modification to other characters such as earliness, grain quality and yield. The double homozygotes are more productive and sligthly later than Cappelli and than the either parent mutants Castelporziano and Castelfusano. Minor mutations (mutations with less phenotypic expression) often accompany major mutations: plant height as in this case. The presence of the minor mutations can be detected in derivatives of the backrosses, thus permitting the isolation of the main mutation which in so doing, can be cleaned of all other aberrations and other deleterious minor effects. The minor mutations are sometimes positive in that they can modify the expression of the major mutation or alternatively can increase the variability of other quantitative characters. The mutant Cp B144 from Cappelli has good grain quality (i.e. high 1000-Kernel weight, low yellow-berry), other than lower stature as compared with the mother variety. These traits have been particularly useful for the improvement of the quality. In fact from the cross of the mutant Cp B144 with mexican lines carrying Norin-10 dwarfing genes, good lines have been selected and released as new outstanding cultivars with the names CRESO and MIDA. These varieties add to the wellknown good agronomic characteristics of the mexican material (short straw, high spike fertility, photoinsensitivity, high yielding capacity, etc. etc.) good technological quality of the Cp B144 (high 1000-grain weight, good test weight and good quality of the pasta) [36, 37, 38].

A complete list of the durum varieties obtained at the Casaccia Nuclear Center, from direct mutants of from crosses with mutants, is shown in the table 1.

6. CONTRIBUTION OF THE MUTAGENESIS TO THE EVOLUTION OF NEW CULTIVARS IN DURUM WHEAT

To this purpose is worth showing a sinthetic picture dealing with the present panorama of durum wheat varieties cultivated in Italy [39].

The Italian durum varieties can be divided in three groups according to their genetic development and agronomic characteristics.

In the first group, Cappelli and Capeiti are included; the last one is still now the most cultivated in Italy.

In the second group there are some varieties with specific improvement in comparison with Capeiti: Trinakria, Maristella, Hymera, Castelporziano, Raineri, Polesine, Montanari, Granato, Eliodoro, Campomoro and Sincape 9. Their

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TABLE 1. - Mutants and varieties released by the Casaccia Nuclear Center, CNEN.

Varieties or mutants	Parents	Mutagenic treatment	Main improved attributes
Castelfusano	Cappelli	Thermal neutrons $1,05 \times 10^{13}/cm^2$	yield and lodging resistance
Castelporziano	Cappelli	Thermal neutrons $8,38 \times 10^{12}/cm^2$	" " " "
Cp B 144	Cappelli	X-rays 20 Kr	grain properties
Casteldelmonte	Grifoni	Fast neutrons 100 reps	yield and lodging resistance
Castelnuovo	Garigliano	X-rays 15 Kr	" " " " "
Creso	Cp B 144 x $\overline{(Yt54N10\text{-}B)Cp^2\text{-}63}/Tc^2$	____	very high yielding ability
Mida	Cp B 144 x $\overline{(Yt54N10\text{-}B)\text{-}Cp^2\text{-}63}/Tc^2$	____	" " " "
Tito	Castelporziano x Lakota	____	" " " "
Augusto	(Castelporziano x Lakota) x Casteldelmonte	____	" " " "

yielding ability and adaptation are not significantly higher if compared with Capeiti. Some of them are early flowering and early ripening and can escape to drought. Trinakria is the best one for protein content and even for tecknological quality. Another one, Appulo, exhibits usually good agronomic performances in Southern Italy and is largely cultivated, though it is susceptible to lodging, rusts and mildew. Otherwise all these varieties do not utilise properly the very good agroclimatic conditions because of their lodging and desease susceptibility. The very new high yielding varieties are included in the third group. Valsacco, Valnova, Valgiorgio, Valfiora,Creso Valnera, Valselva and TITO. All of them, except TITO, are semidwarfs types with Norin-10 genes. TITO is the only one durum variety wich is competitive in yielding ability and lodging resistance with the semidwarf types. It was selected from a cross between Lakota and Castelporziano, wich is a short straw radioinduced mutant from Cappelli. Tito represents a valid altrnative to the "monocolture" of Norin-10 types in the very good agroclimatic conditions. Compared with Capeiti, all of them are late flowering and late ripening, some show remarkable resistances to stem rust, leaf rust and mildew. Yellowberry can be easily avoided by proper applications of nitrogen fertilizers, wich are "a must" for these varieties. They are recommended for very fertile soils with good availability of water and fertilizers. In such conditions their yielding ability is competitive with bread wheats. In the table II, the grain yields of bread wheats and durums (Capeiti, Creso and Tito) are compared in more than 80 trials performed in Central Italy in the period 1970 - 1976 [40]. The yielding ability in new durums is not less than in new bread wheats and this behaviour is largely confirmed by the data in the farms.

In durum wheat grain filling and ripening period are longer and more elaborated than in bread wheats and this facts could represent an uncertain factor mainly in yielding stability. On the other hand desease resistance (mainly stem rust and mildew) are easily incorporated in these tetraploids. In 1977 an heavy attack of stripe rust, unusual in Italy, damaged the majority of the Italian bread wheats without serious attack on many durum varieties.

The genetic progress obtained in yielding ability is clearly illustrated in the fig. 1. The data are referred to the new lines selected at the C.S.N. Casaccia (Rome) and included in the comparative trials, for each year,

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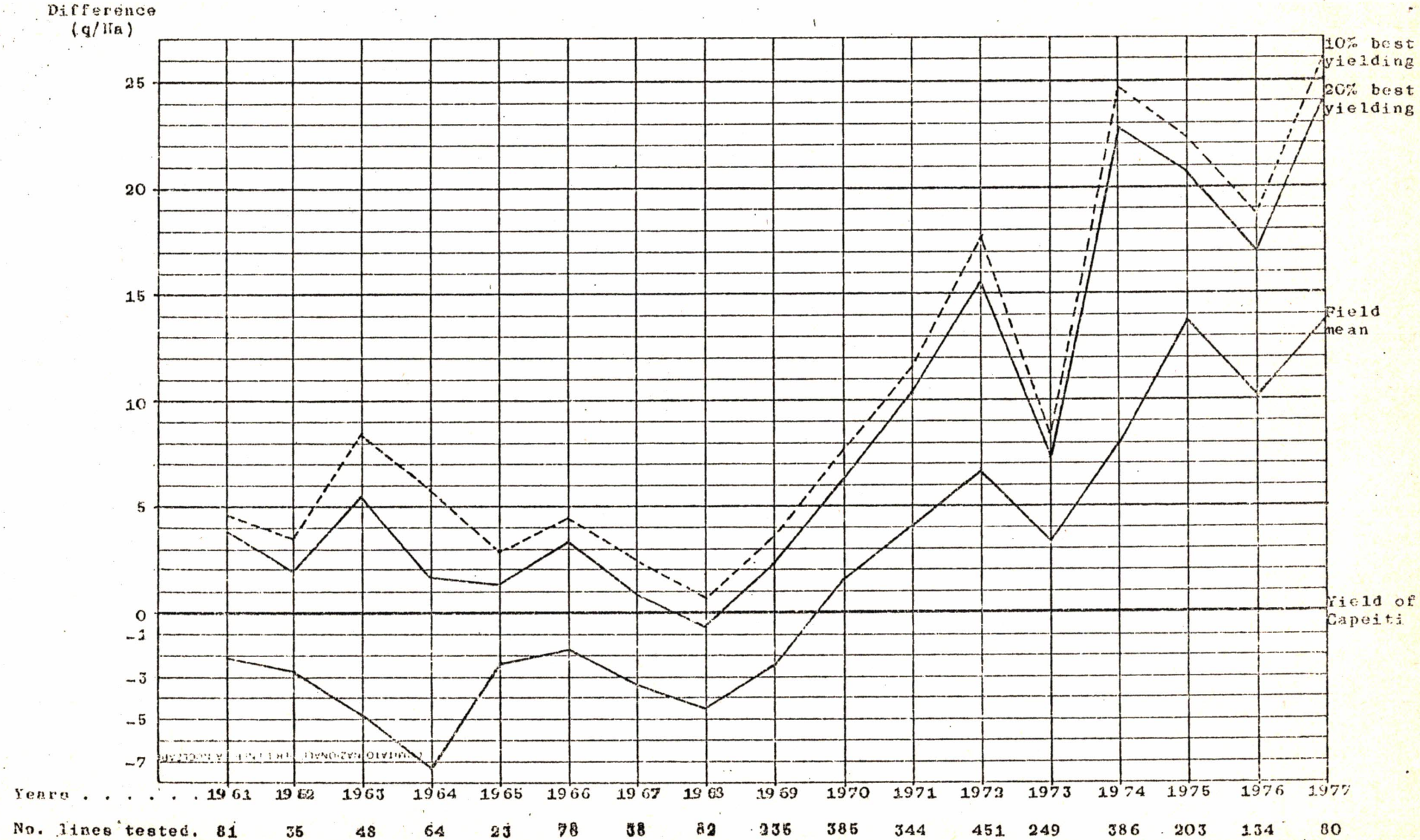
Table 2. Yield and hectolitric weight of bread and durum wheats obtained in 80 agronomic trials conducted in central Italy in the last 8 years

	Bread wheats	Durum wheats		
	Irnerio or Flaminio	Capeiti	Creso	Tito
Mean yield (q/Ha)	54.01	40.56	58.83	58.43
Mean hectolitric weight (kg/hl)	77.65	81.29	81.95	77.37

(After Bozzini, Mosconi, Rossi, 1978)

FIG. 1 - DIFFERENCES IN YIELD (Capeiti = 0) OF DURUM LINES TESTED AND SELECTED (10% - 20%)



from 1961 to 1976. Capeiti is considered the test variety and the differences in yield from Capeiti of the "field average", the "10 % best lines average" and the "20 % best lines average", are reported.
From 1961 to 1968 the number of the lines included every year in the trials was less than one hundred, later it was more than two hundred.
Until 1968 the "field average" was significantly less than Capeiti and no appreciable improvement was obtained. From 1969 to 1974 the improvements of the new lines appear clearly very rapid and significant.
The utilisation (fig. 2) of new short straw lines (from mutants and mainly from Norin-10 genes) and the incorporation of rust and mildew resistances, were the determinant factors of this rapid genetic improvement.
To evaluate the contribution of the mutagenesis, apart from the cultivars Creso and Tito, is useful to look at the fig. 3 where /41/ the lines, developed at C.S.N. Casaccia from 1961 to 1977, each year for the first time in agronomic trials, are distinguished in four groups according to their genetic origin:

- direct mutant lines
- lines coming from crosses with mutants
- lines carrying Norin-10 dwarfing genes
- lines coming from crosses involving neither Norin-10 nor mutants.

It can be noticed that in the beginning the genetic material undergoing field trial was represented almost exclusively by pure mutants, as a result of the big effort devoted to the induction of mutations.
During the period 1965 to 1967 corresponding to the development of a big cross-breeding programm involving mutants and varieties, appear in agronomic trials some lines coming from crosses of local varieties available at that time. However, being their natural variability estremely reduced it was not possible to obtain significant genetic improvements. Starting from 1969 the availability of lines coming from crosses of mutants and mexican material (Norin - 10) produced a big jump in terms of yield. From now owards the number of direct mutants decreases drammatically, whilst the derivatives of the crosses between mutants and varieties keep on a good level, despite the big impact of the Norin-10 short straw material.
The success of the selections carrying genes from Norin-10 can be given for granted in highly fertiles soils occurring in the are surrounding Casaccia Nuclear Center, but in

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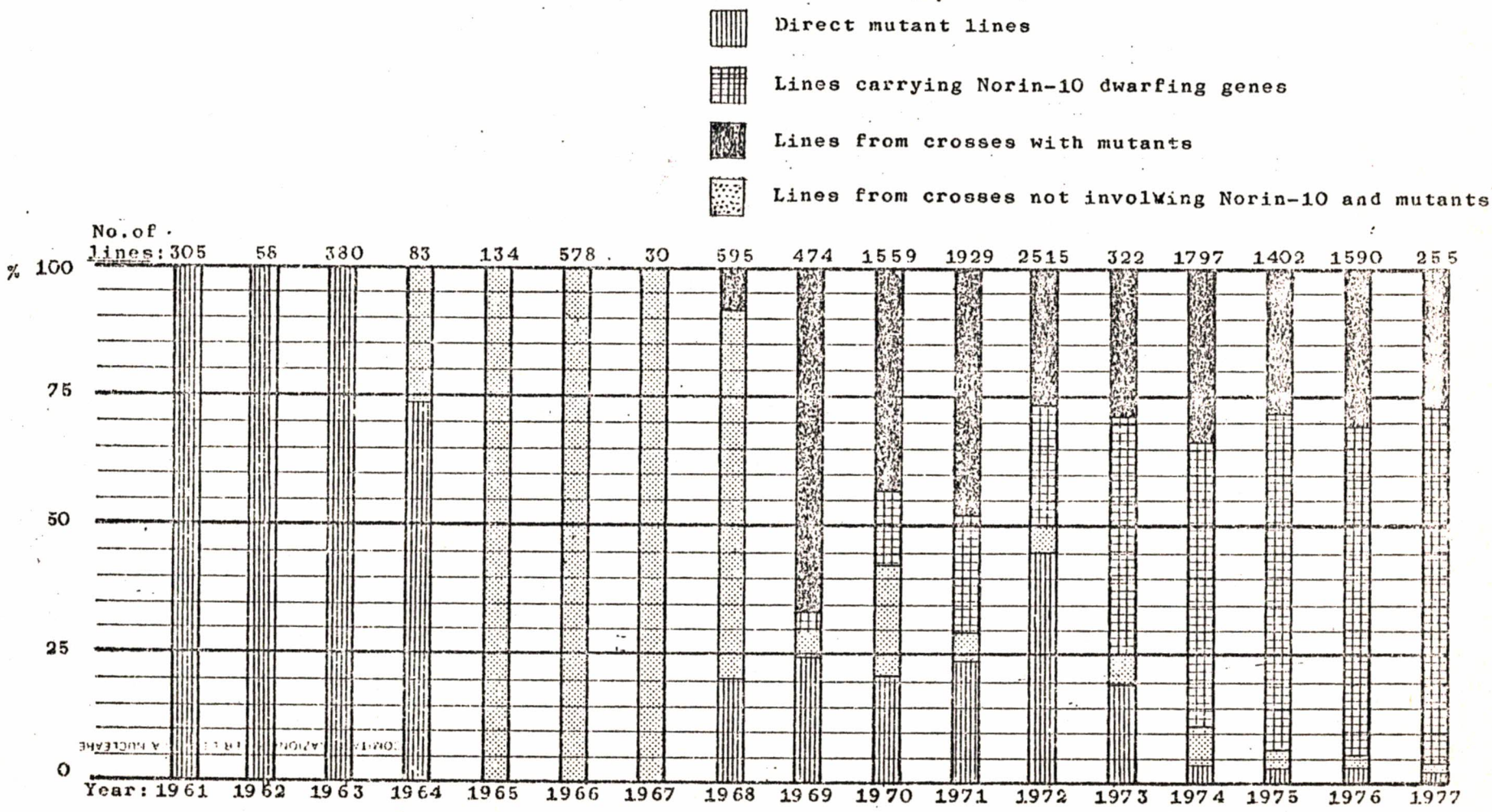
FIG. 2 - DIFFERENCES IN HEIGHT (Capeiti = 0) OF DURUM LINES TESTED AND SELECTED (10% - 20%)

FIG. 3 - TOTAL NUMBER OF LINES EACH YEAR FOR THE FIRST TIME IN AGRONOMIC TRIALS AND % OF COMPOSITION FROM THE FOUR CATEGORIES ESTABLISHED



zones sub-arid typical of Mediterranean Area it is likely to infer a better adaptability of the mutants over Norin-10 material. This pattern comes up frequently in trials carried out in South Italy, particularly in Sicily where mutants for earliness induced in Capeiti seem to be very promising and they are largely used in crosses.
Trying to understand the main reasons of the remarkable success of durum wheat programme, we must underline the following points: "primitiveness" of the species, great efforts on radiogenetical and fundamental studies, integration of different breeding tecniques, adoption of valid methodology of isolation and evaluation of the new derivatives. In the table III is reported a synthesis of 17 years (1961 - 1977) of agronomical evaluation and selection of the new lines obtained in the Casaccia Center [41]. By using this agronomical procedure it was possible to discard every year about 70-80% of the lines in trials (98.4% of the initial number in only 3 years), therefore many new lines could be tested and properly evaluated.

7. ECONOMIC EVALUATION OF THE CULTIVARS OBTAINED BY MUTATION BREEDING

Among the varieties released (Castelporziano, Castelfusano, Casteldelmonte, Castelnuovo, Creso, Mida, Tito, Giano, Febo and Augusto) Creso is the most important from an agronomic and economic point of view.
It was released in 1974 and more than 350.000 Ha were cultivated in Italy in 1977-78. The mean yield over all the Italian surface was estimated in 1976 as 3.16 tons/Ha against 1.75 tons/Ha for Capeiti and 2.12 tons/Ha for Patrizio. The higher yields of Creso are explained even by the better agroclimatic condition compared with Capeiti and Patrizio. Understimating a benefit of 0.9 tons/Ha, the total benefit for Italy in 1978 due to Creso amounts to 315.000 tons, equivalent to $ 7. millions. The surface cultivated with this new variety is in rapid expansion as we can realise looking at the data on the certified seeds.
The percentages on total durums certified seeds are reported according to the relative contributions:

	1972	1973	1974	1975	1976
Capeiti	38.7	33.3	37.1	35.9	25.4
Patrizio	36.8	35.1	33.4	31.0	21.3
Creso	-	-	1.1	5.0	16.5

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Tab. 3. - Synthesis of 17 years (1961-1977) of agronomical evaluation and selection of new lines of durum wheat obtained in the Casaccia Center.

Year	Number of lines tested	Number of trials	Number of replications	Plot size m^2	Selected lines (% of tested)	Selected lines (% of initial No.)
1st	13.500	1	2	1-2	21.6	21.6
2nd	2.922	1	4	6-8	30.8	6.7
3rd	900	2-4	4	10-12	24.6	1.6
4th	221	3-5	4	10-12	26.7	0.4
5th	59	5-10	4	10-12	40.0	0.18

The data for 1977 were not available but it is reasonable to estimate a proportional increase of Creso and decrease of Capeiti and Patrizio.
Trying a balance we can estimate the cost of mutation breeding on durum wheat, conprehensive of the studies on radiobiology, mutagenesis, cytology and cytogenetics, genetics and breeding, carried out in the last 15 years in the C.S.N. Casaccia about 3.5 milions $. Obviously some of these data are approximative but they represent globally the real situation.

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MUTATION BREEDING OF *DURUM* WHEAT

1. Introduction
2. Radiogenetical studies
3. Isolation of potential useful mutations
4. Agronomic evalutation of mutant lines
   a) In Italy
   b) International co-operative trials
5. Use of mutations in hybridization programs
6. Contribution of the mutagenesis to the evolution of new cultivars in *durum* wheats
7. Economic evalutation of the cultivars obtained by mutation breeding

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