M. Feldman

A durum wheat of high protein content useful for breeding purposes

G.ZITELLI, B.M. MARIANI, E.BIANCOLATTE and J.VALLEGA

Experiment Institute for Cereal Research of Rome, Italy.

SUMMARY

The durum wheat varieties cultivated in Italy, as a whole, are not very high as protein producers. However, among them Trinakria, a variety bred in Sicily, has shown, in trials conducted for three years in different localities (40), to have a constantly high protein content when compared to other varieties grown in this country.

A diallel crossing system (8x8) including Trinakria was made. Protein content expressed as percentage and mg per seed, and 1000 seed weight were examined.

The Griffing combining ability shows that Trinakria transmits to F_1 hybrids its high protein content. This is a result of the primarily additive genetic effects as indicated by a greater value of general combining ability mean squares.

Very high broad heritability for all three mentioned characters was found.

1978

New Delhi, 1978

The durum wheat varieties cultivated in Italy, as a whole, are not very high protein producers. Although differences exist among them, they are rather close to the average value (about 12% of dry matter) of the varieties cultivated in the world (VOGEL et al., 1973). Consequently, it is of special interest finding genetic sources for high protein content, in order to change by breeding the present status.

In the case of durum wheat, the importance of increasing the protein content is not only related to the interest of improving the nutritional value, but also connected with the possibility of producing better "spaghetti". Moreover, the protein is highly variable for a given genotype; therefore it is needed to study the different varieties comparatively and repeatedly in several environments and in different years (VALLEGA, 1977), unless it is dealt with very differentiated material under such respect.

Field data, obtained from many localities and for several years, have shown that the variety Trinakria(°) is superior to all other Italian varieties in protein content. This confirms what the Trinakria breeders (BALLATORE, 1970) had indicated since the beginning.

(°) Trinakria, a cross between B14 (selection from North-Africa) and Capeiti, bred in Sicily by the Institute of Agronomy - University of Palermo.

MATERIAL AND METHODS

Twenty durum wheat Italian varieties were grown in 1975, 1976 and 1977 in 40 localities of Central, South and main Islands (Sicily and Sardinia) of Italy. In fig.1, the distribution of experimental fields is presented: 8 locations in 1975, 14 in 1976 and 18 in 1977.

A randomized block design with four replications was used. Each plot consisted of 8 rows 17 cm apart and 7.5 m long (about 10 m^2); the seeding rate was about 450 seeds per m^2.

Among all the varieties included in the trials, only 16 were common during the three years and eight of them have been selected to evaluate the Trinakria performance. Trinakria was compared with Cappelli and Capeiti, which are fairly old varieties still largerly cultivated, and five other varieties - Creso, Polesine, Tito, Valfiora, Valgerardo - rather new.

The traits studied are the following:

- % of protein in the grain (13% of moisture), measured by Technicon Infraalyzer system;
- protein per seed, mg;
- weight of 1000 seeds (13% of moisture);
- yield of protein, q/ha.

In order to characterize the 8 selected varieties, agronomic traits as grain yield q/ha, plant height, and test weight have been considered.

For the 1976 and 1977 data, two different correlation coefficients have been calculated among protein content (% and mg per seed), 1000 seed weight and grain yield q/ha. One (named general) has been obtained from the location means (of 20 varieties); the other has been calculated for the single selected varieties on the basis of the average values presented by each varieties in the different localities.

Finally, a diallel cross system without reciprocal combinations among the varieties Cappelli, Jucci, Trinakria, Taganrock, Valgerardo, Valtarquinio, Giorgio 679, Duro Lucano has been studied.

Parental varieties and F_1 were grown in 1976 at Rome; the experimental design was a randomized block with two replications. The plots were represented by the rows 1.5 m long and spaced 30 cm apart; space between plants in each row was 5 cm.

Protein percentages expressed on a 13% moisture basis, protein per seed (mg) and 1000 seed total weight were analysed.

Estimates of general and specific combining ability were obtained by the diallel cross analysis according to GRIFFING (1956), method 4 (only F_1), model 1 (information derived from this study applies only the cultivars studied).

Broad sense hereditability was calculated using the variance component method.

RESULTS AND DISCUSSION

A) Field trials

In table 1, for each year, are reported the average values of protein content (% of protein, amount of protein per seed, protein yield q/ha) and other traits of agronomic importance, useful for characterization of the eight varieties selected for this study. Trinakria shows the highest values for protein expressed in %; the amount of protein per seed (mg) is also high, but cannot be considered the optimum in absolute sense; the yield of protein in q/ha is intermediate because of the relatively low grain yield.

Table 2 reproduced the protein % values of the varieties in different years. Trinakria appears as the wheat that systematically gives the highest protein content. In every year not only offers the best average values, but also the minimum and maximum highest limits, as well as a relative low variability coefficient. In 1977 Tito and Polesine show a maximum value superior to those of Trinakria as consequence of their high percent of shrinked seeds.

Fig.2 shows the protein content (%) for variety in relation with the protein means of the different localities. The places with average values differentiating not more than 0.5% have been pooled. The Capeiti and Polesine varieties have not been included: the former because of the poor interest for the protein trait, the latter because of the fact that the high

protein values are mainly due to the small size of the seed and the shrinking.

From fig.2 the systematic superiority of Trinakria is evident in the years and localities. Valfiora and Cappelli have a pattern similar to that of Trinakria but lower values. Valgerardo shows higher protein content (%) in locations with higher % values, indicating that it can profit of a better nitrogen availability (VALLEGA, 1977).

Table 3 reports the correlation coefficients among protein %, grain yield q/ha, 1000 seed weight, and protein per seed, both in general and for each of 8 selected varieties.

In general (considering the 20 varieties) a negative correlation between protein % and grain yield was found only in 1976; however this is not systematic, if the single varieties are considered. In fact in 1976 the eight varieties, except Tito, show a positive trend (although not significant): namely increasing of yield is accompanied by increase of protein %. For Creso and Capeiti actually such a positive correlation is significant at the 5% level.

In 1977 data, a negative and significant correlation is found between protein % and 1000 seed weight according to the results reported by BATHIA (1975), FAVRET (1970) and JAIN (1976). In 1976, on the contrary, the correlation is not significant and in general there is a positive trend. However, it must be considered that in 1977 there has been

a long period of dry season during the vegetative cycle of the plant, especially in Southern Italy. This has been the cause of the low yield in grain and of the low value of 1000 seed weight.

The 1976 data give a positive correlation, highly significant between protein % and amount of protein per seed, both in general and for each variety, except Creso. On the contrary in 1977 the trend is negative in general, whereas for single varieties such a trend is apparent only in Creso and Polesine. This result suggest that, at least for the varieties tested and in favorable seasons, the increase of seed weight is not always associated with a lower protein production.

A significant positive correlation has been found between amount of protein per seed and 1000 seed weight, both in general and in each varieties, except Tito for both years. A similar positive correlation, statistically significant, between such traits has been observed also in bread wheat, barley, and rice by several authors: FAVRET et al. (1969), HARN et al. (1973), BATHIA (1975), JAIN et al. (1976).

Such findings suggest that it is necessary to select, in early generations, plants or progeny with high seed weight and high percentage of protein, to obtain lines with high protein content without yield decrease. In fact, the cited authors suggest that the great amount of protein per seed is the best criterion for making selection in breeding programmes.

B) Diallel cross analysis

In order to obtain a better knowledge of the performance of the parental lines, in terms of their ability to combine in hybrid combinations, and since the mean squares for all the characters were significant among genotypes, a combining ability analysis was performed.

Such analysis involved the protein content, expressed as percentage and mg per seed, and 1000 seed weight.

The observed mean squares of the general and specific combining ability and their significance are given in table 4. The variances of general combining ability (GCA) are highly significant for all the considered traits (BRIGGS, 1974); the same occurs for the specific combining ability (SCA) variance with the exception of that for the protein percentage, that is significant at P=0.05 level, only.

In comparing the relative magnitude of general versus specific combining ability, the largest part of the total genetic variability is associated with GCA for all traits. This would indicate that the 3 measured characters depend mainly on additive gene actions, at least on the basis of the genetic background used in this experiment.

This result is interesting because the additive gene action only can be retained by segregating generations in self-pollinating crops as durum wheat.

To better evaluate the genetic potential for grain protein content of the individual varieties included in this diallel system, estimates of GCA and SCA variances associated with each parent have been calculated (Table 5). Trinakria is the only variety that presents high variances for GCA, consistently superior to that of SCA, for all the three characters important for the protein content. Therefore the trait "high protein content" of Trinakria is mainly a result of additive gene actions, and the same applies to 1000 seed weight. As a consequence, such traits should be easily transmitted to the progenies following hybridization of Trinakria with other genotypes. Then, it should be possible to select segregants with elevated expression of the protein content and great seed weight.

Cappelli, on the contrary, presents a reverse situation: protein % shows a SCA variance about twice as great as GCA variance. This means that non additive gene action plays the most important role in determining protein content in Cappelli and, consequently, the F_1 performance is difficult to be preserved in successive generations. For protein per seed and for 1000 seed weight the additive gene actions appear slightly more important (GCA/SCA variance ratio = 1.5). The new varieties Valgerardo and Valtarquinio show variance values quite low and, anyway, the superior estimates are for SCA for the three traits.

The estimates of GCA effects are presented in table 6. The largest positive effect for all the 3 characters is con-

tributed by Trinakria. This wheat easily transmits its high protein content (% and mg per seed) and high 1000 seed weight to hybrids, as indicated also by the higher values of variance obtained for GCA as compared to that of SCA. The F_1 means are largely greater than the value of Trinakria that results, therefore, the most outstanding parent.

On the contrary, Cappelli shows high negative estimates of the effects of GCA for the three characters studied. This fact, together with the findings obtained for the GCA and SCA variances, could explain why the majority of Italian varieties derived from Cappelli have not the quality level of Cappelli.

One of the new promising varieties, Valgerardo, shows low values of GCA effects for the three characters, and its hybrids are very close to Valgerardo. With respect to the other parents, except the remarkable effect of GCA of the line Giorgio 679 for the character 1000 seed weight, nothing of special interest has been observed.

In order to put in evidence and to compare the hybrids derived from the three most interesting parents (Trinakria, Cappelli and Valgerardo), the values of the hybrids and the most significant estimates of the SCA effects, both positive and negative, are represented in fig.3. Considering the protein %, it is evident that all F_1 hybrids, derived from crosses with Trinakria, have a constantly higher protein content than Trinakria. The hybrid with the highest value (16,42) is Trinakria x Valgerardo that, however, shows a great SCA effect. There-

fore the possibility to fix lines with protein % so elevated in successive generations will be more difficult. Other two hybrids with high protein content are Trinakria x Giorgio 679 and Trinakria x Jucci. On the other hand, Cappelli x Valtarquinio, shows a large SCA estimate. Trinakria x Valtarquinio, and Cappelli x Valgerardo present great but negative estimates of SCA effects; in other words, they produce lower protein contents that could be expected on the basis of the parental performance.

A similar response is given by the mentioned hybrids (fig.3) with respect to the amount of protein per seed (mg).

The hybrids with seed weight highest values are those of Trinakria when crossed with Valgerardo, Giorgio 679, Duro Lucano and Jucci (that also have the best protein contents), and Cappelli x Giorgio 679 that, in addition, presents a great SCA effect.

The broad sense heritability estimates, obtained from the variance components of the F_1 data, for the protein %, the amount of protein per seed, and the 1000 seed weight, were respectively 83, 95, and 90%. These high heritability values, together with the fact that the characters involved are mainly due to additive gene actions, suggest that it should be relatively easy to select for a higher protein content, as has also been indicated by KONZAK (1977).

Literature cited

BALLATORE, G.P.,1970 - Due nuove cultivar di grano duro.
L'Informatore agrario, 38: 2947-2949.

BHATIA, C.R., 1975 - Criteria for early generation selection in wheat breeding programmes for improving protein productivity.
Euphytica, 24: 789-794.

BRIGGS, K.G., 1974 - A study of combining ability for grain protein percentage in a diallel cross of five six-row barley cultivars.
Can. J.Plant Sci., 54: 605-609.

FAVRET, E.A., L. SOLARI, L. MANGHERS, and A. AVILA, 1969 - Genetic control of the qualitative and quantitative production of endosperm proteins in wheat and barley.
New Approaches to Breeding for Protein
(Proc. IAEA Symp., Vienna): 87-107.

FAVRET, E.A., L. MANGHERS, L. SOLARI, A.AVILA, and J.C. MONESIGLIO, 1970 - Gene control of protein production in cereal seeds.
Improving Plant Protein by nuclear techniques.
(Proc. IAEA Symp., Vienna): 87-97.

GRIFFING, B., 1956 - Concept of general and specific combining ability in relation to diallel crossing systems.
Aust. J. Biol. Sci., 9: 463-493.

HARN, C., J.L. WON, C.K. PARK, and J.Y.YOO, 1973 - Mutation breeding for improvement of rice protein.
Nuclear Techniques for Seed Protein Improvement.
(Proc. IAEA Symp., Vienna): 115-137.

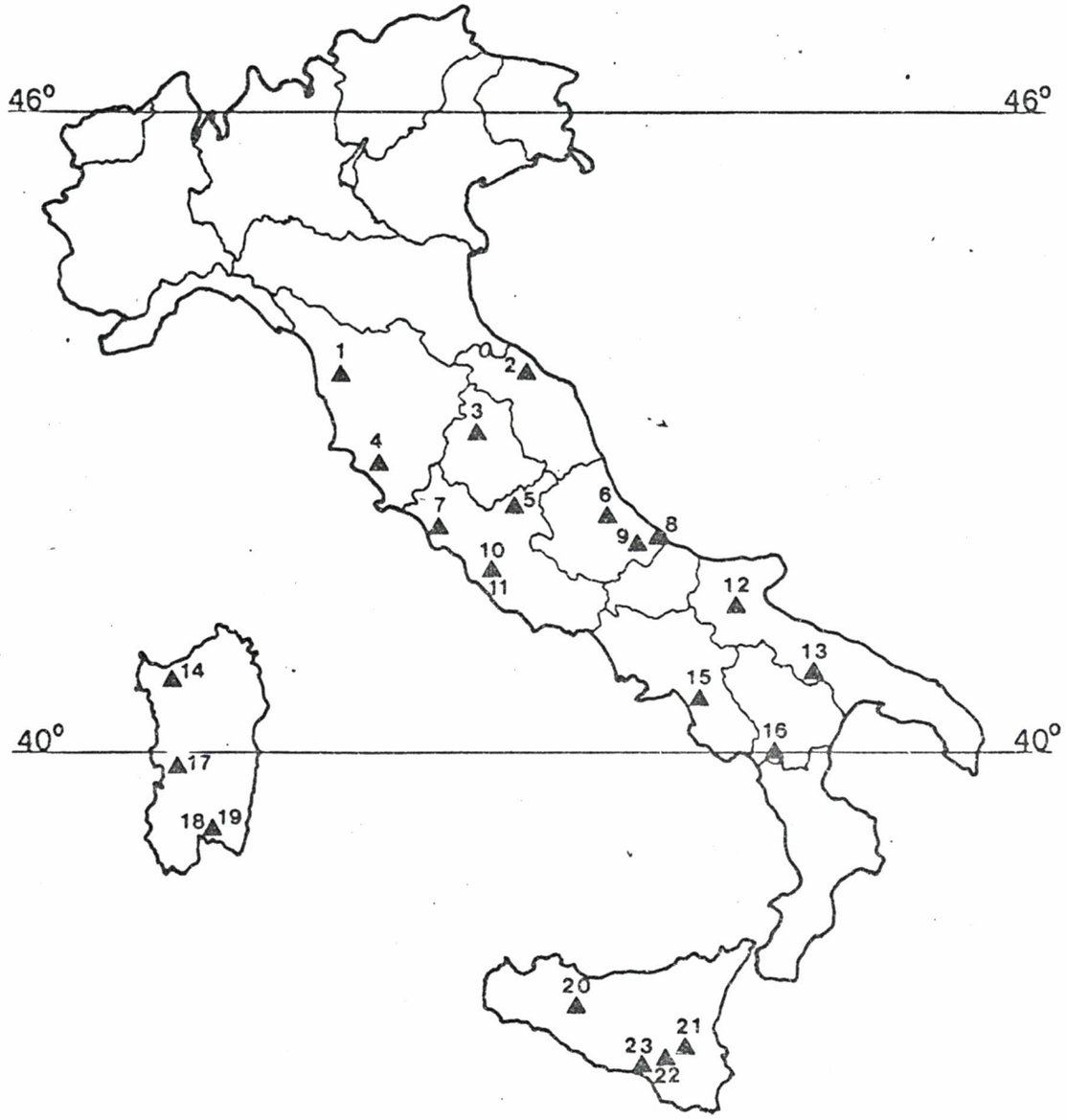
JAIN, H.K.,N.C.SINGHAL, and A. AUSTIN, 1976 - Breeding for higher protein yields in bread wheat: Experimental approach and a phenotypic marker.
Z. Pflanzenzuechtg., 77: 100-111.

KONZAK, C.F., 1977 - Genetic control of the content, amino acid composition, and processing properties of proteins in wheat.
Adv. Genetics, 19: 407-582.

VALLEGA, J., 1977 - Grano duro: facciamo il punto sulle nostre varietà.
L'Informatore agrario, 21: 26649-26697.

VOGEL, K.P., V.A. JOHNSON, and P.F. MATTERN, 1973 - Results of systematic analyses for protein and lysine composition of common wheats (Triticum aestivum L.) in the USDA World Collection.
Agr. Exp. Sta. Univ. Nebraska: Res. Bul.258:1-27.

FIG 1 - FIELD TRIAL LOCATIONS IN 1975,1976,1977.



N	LOCALITIES	1975	1976	1977
1	PISA	*		
2	IESI			*
3	PERUGIA		*	*
4	GROSSETO	*		*
5	RIETI	*		*
6	CEPAGATTI (PE)	*		
7	TARQUINIA (VT)		*	*
8	VASTO (CH)		*	*
9	SCERNI (CH)			*
10	ROMA	*	*	*
11	PONTE GALERIA (RM)			*
12	FOGGIA		*	*
13	GRAVINA (BA)		*	*
14	OTTAVA (SS)	*	*	
15	BATTIPAGLIA (SA)	*	*	*
16	CASTELLUCCIO (PZ)		*	
17	ORISTANO	*	*	
18	BENATZU (CA)		*	*
19	USSANA (CA)		*	*
20	SPARACIA (PA)		*	*
21	MINEO (CT)			*
22	CALTAGIRONE (CT)			*
23	GELA (CL)		*	*

FIG. 2 – PATTERN OF PROTEIN PERCENTAGE FOR SIX SELECTED VARIETIES VERSUS MEAN OF PROTEIN PERCENTAGE FOR EACH LOCATION (similar location means are grouped and averaged) IN

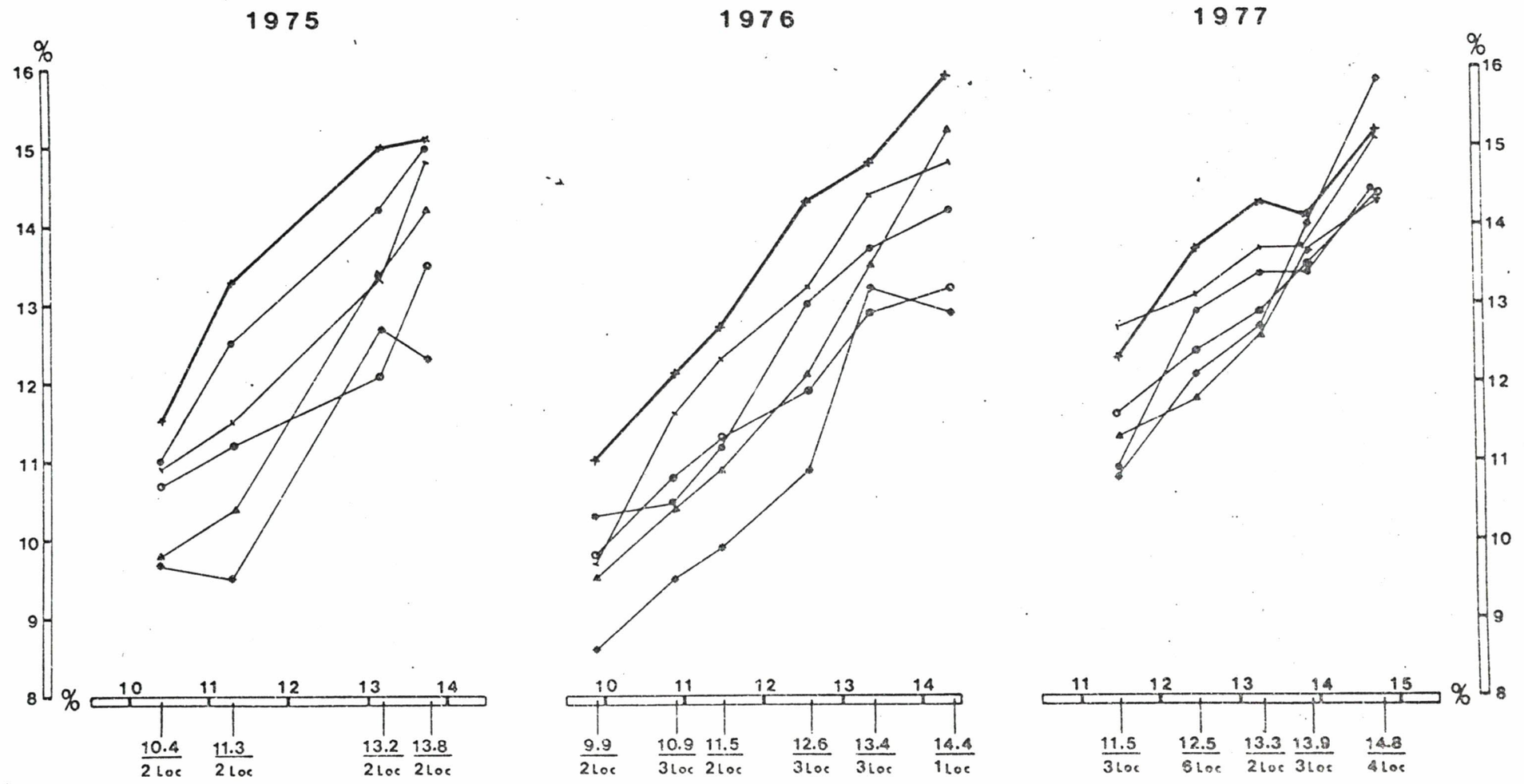
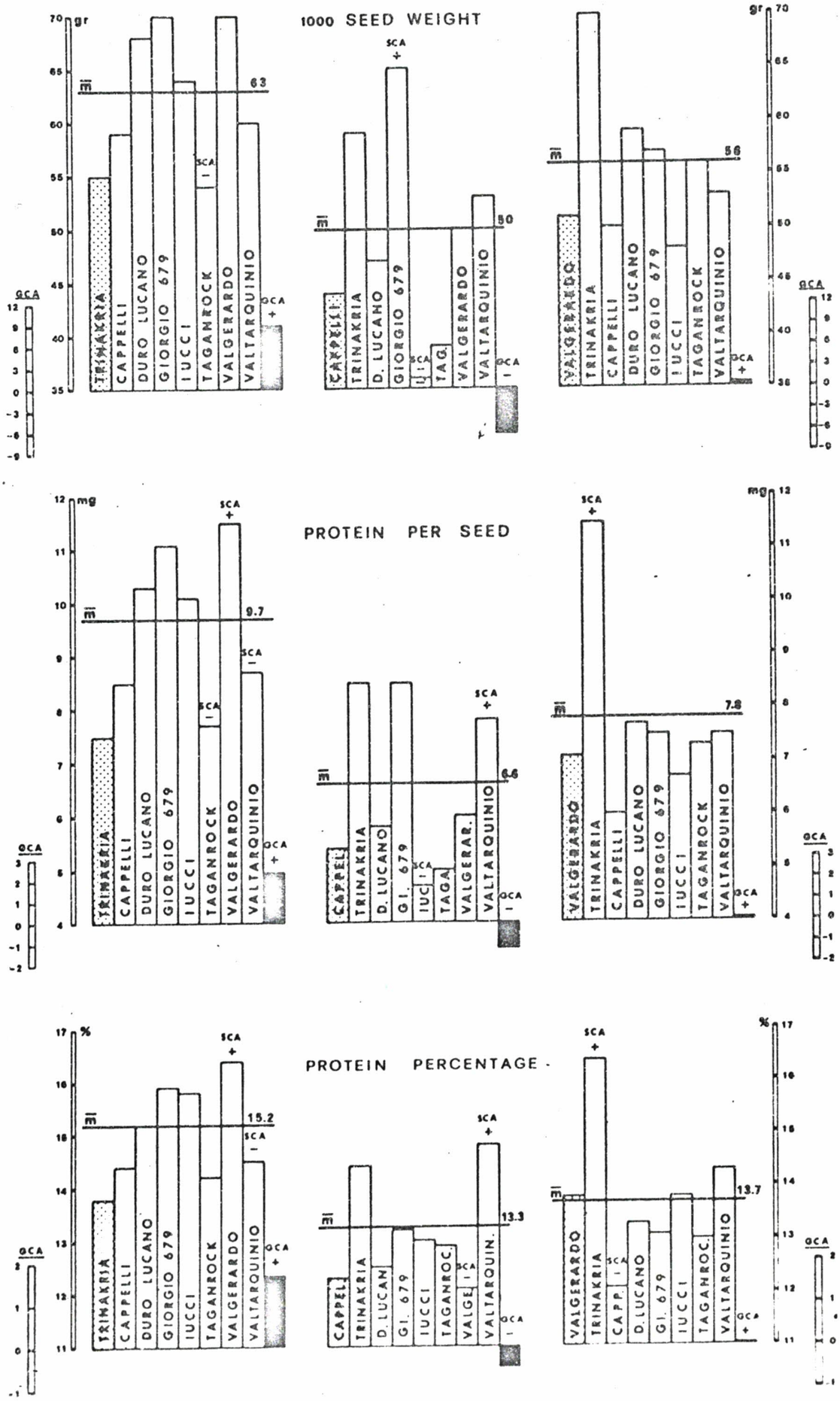


FIG 3- DIAGRAM FOR TRINAKRIA, CAPPELLI AND VALGERARDO AND THEIR F_1 HYBRIDS WITH THE OTHER PARENTS FROM THE DIALLEL SET (8 x 8).



TAB.1 – Protein content and some agronomic traits for eight varieties in 1975, 1976, 1977 *

		GRAIN PROTEIN %	PROTEIN per SEED mg	PROTEIN YIELD q/ha	GRAIN YIELD q/ha	1000-grain WEIGHT g	TEST WEIGHT kg/hl	PLANT HEIGHT cm
TRINAKRIA	1975	13.7	–	5.6	41.7	–	79	116
	6	13.3	5.9	4.0	29.7	45	76	113
	7	13.9	6.3	4.2	30.3	46	79	101
CAPPELLI	1975	13.2	–	4.9	37.5	–	81	139
	6	12.0	5.9	3.5	28.5	49	76	135
	7	13.0	5.8	3.1	24.1	45	79	125
CAPEITI	1975	11.9	–	5.6	47.3	–	80	112
	6	11.4	4.8	3.8	33.0	42	77	112
	7	12.4	5.0	2.9	23.6	40	80	96
CRESO	1975	12.0	–	7.0	58.0	–	82	87
	6	11.6	5.6	4.7	40.5	49	78	80
	7	12.9	6.2	4.5	34.9	48	82	76
TITO	1975	11.0	–	5.7	52.9	–	79	101
	6	10.7	4.0	4.0	37.7	38	73	95
	7	13.1	4.4	3.8	29.6	34	76	81
VALFIORA	1975	12.5	–	6.4	51.9	–	79	94
	6	12.6	6.4	4.2	32.5	51	75	85
	7	13.6	7.2	4.4	32.5	53	80	81
VALGERARDO	1975	11.9	–	6.7	57.4	–	80	94
	6	11.7	5.5	4.5	37.9	47	76	90
	7	12.7	6.0	5.2	40.7	48	81	81
POLESINE	1975	–	–	–	–	–	–	–
	6	12.9	4.8	4.2	31.9	37	74	98
	7	14.1	4.9	4.0	28.6	35	78	84

* 1975: means for 8 localities;
1976: means for 14 localities;
1977: means for 18 localities.

TAB. 2 – Protein content (%) of eight varieties in 1975, 1976, 1977: min. and max. location means, means of all locations and relative coefficients of variability.

Year	1975			1976			1977		
N° of localities	8			14			18		
mean of localities		12.2			12.0			13.1	
Varieties	Min. – Max.	m	CV%	Min. – Max.	m	CV%	Min. – Max.	m	CV%
Trinakria	11.3 – 15.4	13.7	12	10.6 – 15.9	13.3	12	12.0 – 16.1	13.9	8
Cappelli	10.8 – 15.1	13.2	12	9.4 – 14.6	12.0	14	10.8 – 15.4	13.0	10
Capeiti	10.1 – 13.2	11.9	10	9.0 – 13.5	11.4	12	10.5 – 14.8	12.4	10
Creso	10.4 – 13.5	12.0	11	9.6 – 13.2	11.6	10	11.1 – 15.0	12.9	8
Tito	9.0 – 12.9	11.0	15	7.7 – 14.1	10.7	18	10.0 – 17.5	13.1	15
Valfiora	10.5 – 14.5	12.5	12	9.2 – 15.0	12.6	14	12.3 – 15.4	13.6	7
Valgerardo	9.1 – 14.5	11.9	18	8.5 – 15.2	11.7	15	11.0 – 14.9	12.7	10
Polesine				10.4 – 14.8	12.9	11	11.7 – 16.5	14.1	10

Tab.3 – Correlation coefficients for 1976 and 1977, in general (over all varieties and locations) and for each varieties.

		in general	TRINAKRIA	CAPPELLI	CAPEITI	CRESO	TITO	VALFIORA	VALGERARDO	POLESINE
– % of protein vs.:										
– grain yield q/ha	1976	–0.59**	0.37	0.40	0.52*	0.49*	–0.13	0.32	0.27	0.35
	1977	–0.06	–0.23	–0.15	–0.14	–0.31	–0.47	–0.23	–0.10	–0.53*
– 1000 seed weight	1976	0.14	–0.03	0.22	0.18	–0.33	–0.44	0.06	0.10	–0.04
	1977	–0.62**	–0.58**	–0.32	–0.20	–0.65**	–0.76**	–0.45	–0.59**	–0.72**
– protein per seed,mg	1976	0.57**	0.74**	0.78**	0.81**	0.45	0.70**	0.82**	0.84**	0.73**
	1977	–0.08	0.19	0.24	0.39	–0.13	0.24	0.06	0.13	–0.43
–Protein per seed,mg vs. :										
– grain yield q/ha	1976	–0.19	0.56*	0.58*	0.59*	0.11	0.18	0.49*	0.43	0.69**
	1977	0.45	0.11	0.59**	0.17	0.27	0.35	0.01	–0.06	0.52*
– 1000 seed weight	1976	0.89**	0.58*	0.78*	0.73**	0.69**	0.33	0.61**	0.62**	0.65**
	1977	0.83**	0.69**	0.84**	0.82**	0.84**	0.44	0.87**	0.72**	0.93**

* significant at P= 0.05 level
** " " P= 0.01 "