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Study of the Mechanisms of Stability of the Output Grain of Some Durum Wheat Genotypes (*Triticum durum* Desf.) Under Semi-Arid Climate

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Abstract: In Algerian semi-arid zone, the year effect has a significant part in the variation of the output grain, on the other hand the differences between genotypes are no significant. The genotypic selection live has screw of the output must be done per year. The stability of the output is a very complex characteristic dependent on several other variables. The expression of an output in high grain is associated a better performance for the number of grain m^2, the number of grains/ear and the index of harvest. Under constraining conditions, when the number of grain m^{-2} is weak, the genotypes compensate for it by an increase in average pea in order to minimize the fall of the output in grain. The genotypes productive on the other hand present variations inter-season raised for the output the genotypes at average output have intermediate variation.

Key words: Durum wheat · output in grain · semi-arid climate · variation inter-season

INTRODUCTION

Selection of durum wheat (*Triticum durum* Desf.) areas with strong hydrous and thermal constraints did little progress from the improvement point of view of the output grain and the adaptation to the environment. The difficulties lie in the identification and the characterization of the parameters related to the strength to the climatic constraints. The characterization of the mechanisms which control the tolerance with the stresses and their connections with the adaptation to the medium constitutes the research orientation the most topicality.

MATERIALS AND METHODS

Installation of the experimentation: The experimentation was led on the experimental site of station ITGC of Sétif (Algeria). Installation in a device in randomized blocks, with four repetitions, it lasted six consecutive campaigns, from 1997/1998 to 2002/03. The elementary piece consists of 6 rang of 5 m length rows is $6m^2$. Sowing is carried out in November and harvest is made in June. The ten studied varieties are Mohammed Ben Bachir (MBB), Mrb5, Cyprus1, Waha, Derraa, Heider, Adamillo/Duillio//Semito 439-97 (ADS), Heider/Martes//Huevos de Oro (Hmho), Massara1 and Beliouni.

Notation, measurements and analyze data: Taken measurements related to:-The date of realization of the stage épiaison. This date is used for the determination of the duration of the Phase Vegetation (PVG). Air biomass accumulated at the Stage Epiaison BE) and that produced with maturity (BM). The date of realization of the stage maturity. This date is used for the determination of the duration of the phase filling of grain (PRG).

The height of the plants (HT, cm), the ankle boots collected at the stage maturity are also used for counting of ears (NE) brought back to the unit of area (m^2), with the output grain (RDT) estimated starting from the beating of ears coming from the ankle boots to obtain the index of harvest (HI). HI (%) = 100 (RDT/BM). The mechanical harvest of the test gives the output grain (RDT) of compartmental elementary, expressed in g m^{-2}. The weight of 1000 grains (PMG). The number of grains produced per unit of area (NGM^2) and numbers it grains by ear (NGE). $NGM^2 = 1000$ (RDT/PMG), with RDT in g m^{-2} and the PMG in g, NGE = NGM^2/NE.

Once per week, starting from the date of realization of the stage épiaison which was noted to estimate the duration of the vegetative phase (PVG), one samples the vegetation coming from a segment of row of 1m length by elementary piece. The dry matter is obtained after passage to the drying oven with 85°C during 24 h. The speed of vegetative growth (VCV) is determined by the report/ratio

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of the biomass accumulated at the stage épiaison and the duration of the vegetative phase (lifting-épiaison).

The speed of filling per grain (V, mg j^{-1}) is estimated by linear regression. It is taken as being equal to the linear coefficient of regression of the active phase of filling. The duration of filling (D, J) is determined by the report/ratio of the weight of the grain reached with maturity on the speed of filling (V):

D = P1G/V With
D = lasted of filling in days

P1G = average weight of the grain reached at the stage maturity (Mg)

V = speed of filling (mg j^{-1})

The speed of filling brought back t o the number of grains m^{-2} (VRG, g j^{-1} m^{-2}) is obtained by: VRG = (V X NGM^2)/1000 the study of stability was approached by the method of Finlay and Wilkinson [1] for the output grain, the number of grains m^{-2}, the weight of 1000 grains and the index of harvest. The method of Finlay and Wilkinson [1] uses the coefficient of regression (b) to describe the response of the genotypes to the environmental variation.

An analysis of the variance with two not controlled criteria of classification, environment and genotype, was made for the variables measured on the various repetitions. The model adopted in the analysis is the additive model [2]:

$$Y_{ijk} = \mu + E_i + G_j + GxE_{ij} + B(E)_{jk} + e_{ijk}$$

The progressive regression is used if several independent variables are used. Any Co-variable which improves the coefficient of determination (R^2) and tiny room of the residual average square is retained by the model. The analysis in principal components (ACP) is used for a description the complex connections which exist between the variables and their distribution at the various evaluated individuals.

RESULTS AND DISCUSSION

the analysis of the variance shows a year effect and an interaction significant genotype X year for the unit of the variables subjected to the analysis. The genotype effect, tested compared to the variance of interaction, is significant only for the height of thatch and the duration of the vegetative phase (Table 1).

For the whole of the variables, the year effect is by far that which absorbs the greatest part of the variation observed. This indicates that the differences between years or crop years are thus more important relative with the differences observed between the studied genotypes.

Marketing year 1999/00 was most favorable to the expression of high outputs grains. This level of production is associated better performances for the number of grains m^2, of grains by ear, ears m^2. It is also related to a better expression of the index of harvest, measured air biomass with maturity, a long duration of the vegetative phase and with a weak weight 1000 grains (Table 2). Marketing year 2001/02 is that which was most unfavorable with the expression of the output grain with a reduction of the performances for the components of the output, of the duration of the vegetative phase and the produced biomass (Table 2 and Fig. 1).

The differences in expression of the measured variables due to the year effect generally induce interactions genotype X year leading to the instability of the performances of the cultivars in time. The coefficients of correlation show that the years are not very similar for the output grain (Table 3). the effect average genotype is significant only for the height of thatch and the duration of the vegetative phase. The choice of a genotype given, on the basis of one or more of the measured variables, must thus be done per year and not on average of the six campaigns tested. This because of the effect of the interaction genotype X year which is significant.

All the genotypes tested show the same outputs, on average the six years. It is however necessary to identify the genotype which answers most favorably possible the variation of the seasons to be rather regular in production. The study of the coefficients of correlation indicates that the output grain during six years is positively related on the number of grains m^2 ($r = 0.923$, $n = 60$), on the number of grains ear^{-1} ($r = 0.831$) and to the index of harvest ($r = 0.844$).

The number of grains m^2 is positively related on the number of grains ear^{-1} ($r = 0.872$), to the index of harvest ($r = 0.792$) and negatively related to the weight of 1000 grains ($r = -0.681$). These connections show that the production of a number of grains high m^2 led to an index of harvest and a high output grain. A number of grains high ear^{-1} improves the number of grains m^2. A high weight of 1000 grains seems realizable only following the reduction of the number of grains m^2.

The progressive regression indicates that the output is the resultant of the grains produced per m^2, the index of harvest and the weight of 1000 grains:

$$RDT = 0.0253NGM^2 + 1.80HI + 5.21PMG - 170 \ (R^2 = 0.9721)$$

Table 1: Average square of the analysis of the variance

Source	ddl (g m^{-2})	RDT (m^{-2})	NGM^2 (…)	NGE (m^{-2})	NE (g)	PMG (%)	HI
Year (A)	5	160249**	36927750**	1153**	123104**	1468**	1437**
Genotype (G)	9	13796ns	18697188ns	74.9ns	7508ns	38ns	133**
A×G	45	17698**	25551840**	97.7**	12233**	36**	85**
Residual	118	1116.4	1497437	13.0	2105	3.2	16.9
		BE (g m^{-2})	BM (g m^{-2})	VCV (g $j^{-1}m^{-2}$)	VRG (g $j^{-1}m^{-2}$)	HT (cm)	PVG (j)
Year (A)	5	282444**	172959**	22.9**	42.1**	1016**	271**
Genotype (G)	9	117732**	113746ns	5.8ns	5.7ns	1164	80
A×G	45	58960**	97918**	3.9*	6.9**	271**	24*
Residual	118	17407	19680	1.2	0.5	25.5	9.5

NS, *, * * = No Significant, significant effect with the threshold of 5 and 1% respectively. RDT = output in grains, NGM^2 = a number of grains m^2, NGE = a number of grains/ear, = a number of ears m^2, PMG = weight of 1000 grains, HI = index of harvest, BE = weight of the dry matter measured at the stage épiaison, BM = measured biomass with maturity, VCV = vegetative growth rate, VRG = rate of filling of the grain, HT = height of thatch, PVG = lasted of the vegetative phase

Table 2: Averages of the measured variables: Effect year (E), Genotype (G) and interaction G X E

Year	RDT	NGM^2	NGE	NE	PMG	HI	BE	BM	VCV	VRG	HT	PVG
Effect average year												
1997/98	306.9	10416	27.0	393	29.9	31.2	688	995	5.8	5.9	63.2	118
1998/99	315.2	8908	24.7	364	35.5	27.7	836	1151	7.1	5.3	72.2	116
1999/00	357.8	13582	26.9	505	26.8	33.7	691	1049	5.6	7.2	57.6	124
2000/01	326.8	9150	22.6	411	35.9	34.6	623	950	5.3	6.6	68.5	118
2001/02	179.6	4852	13.5	367	37.2	17.2	878	1057	7.4	4.3	65.2	118
2002/03	199.9	4239	13.9	315	47.1	21.9	756	956	6.2	4.3	72.9	122
Average	281.0	8525	21.5	392	35.4	27.7	745	1026	6.2	5.6	66.6	119
Effect average genotype												
Ads	273.5	7637	21.2	354	37.2	28.0	691	965	5.9	5.2	60.5	117
Massara1	237.9	7289	19.4	392	37.3	26.1	691	929	5.9	4.6	62.8	118
Mrb5	300.5	9072	22.3	401	35.2	29.0	739	1039	6.2	5.9	66.5	119
Cyprus1	312.4	10201	23.6	403	34.9	29.3	745	1057	6.2	6.4	63.5	120
Waha	283.7	8490	20.3	416	34.7	29.1	706	989	6.0	5.3	59.9	117
Derraa	298.3	9289	21.9	393	36.2	29.7	703	1001	5.9	6.0	63.2	119
Hmho	312.4	9649	23.9	400	34.7	30.7	720	1033	6.0	6.1	69.6	118
Heider	293.4	8359	24.0	357	38.2	28.5	745	1039	6.2	6.0	63.5	121
Mbb	241.0	7158	17.9	399	35.6	25.3	748	989	6.2	4.9	68.7	122
Beliouni	257.0	8100	20.2	407	33.3	21.5	966	1224	7.8	5.5	87.6	123

RDT = output in grains, NGM^2 = a number of grains m^2, NGE = a number of grains/ear, = a number of ears m^2, PMG = weight of 1000 grains, HI = index of harvest, BE = weight of the dry matter measured at the stage épiaison, BM = measured biomass with maturity, VCV = vegetative growth rate, VRG = rate of filling of the grain, HT = height of thatch, PVG = lasted of the vegetative phase

Table 3: Coefficients of correlation inter-years of the output grain

	1997/98	1998/99	19999/00	2000/01	2001/02	2002/03
1997/98	1.00	-0.142	0.283	0.132	0.327	0.385
1998/99		1.00	-0.723*	0.204	-0.458	0.271
1999/00			1.00	-0.059	0.598*	0.038
2000/01				1.00	-0.220	-0.380
2001/02					1.00	0.288
2002/03						1.00

r = 0. 578 with the threshold of 5%, n = 10

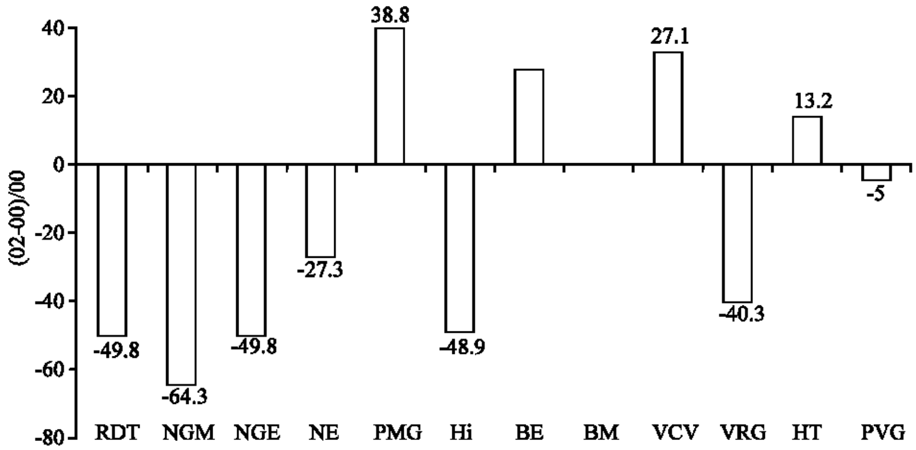

Fig. 1: Difference in expression of the variables measured according to years 1999/00 (favorable to the output) and 2001/02 (unfavorable with the output)

Table 4: Parameters of stability of the output grain, the number of grains m², the weight of 1000 grains and the index of harvest

Character genotype	RDT b	RDT R^2	RDT S^{2*}	NGM² b	NGM² R^2	NGM² S^{2**}	PMG b	PMG R^2	PMG S^2	HI b	HI R^2	HI S^2
Ads	1.35£	87	11.2	0.97º	0.90	12.6	0.66¢	0.53	13.8	1.29£	0.87	92.3
Massara1	0.28ø	17	2.4	0.48ø	0.61	4.5	1.42£	0.48	72.0	0.51¢	0.70	31.8
Mrb5	0.75¢	72	9.8	0.71¢	0.85	13.9	1.19º	0.27	86.4	0.86º	0.74	48.3
Cyprus1	1.12º	76	18.1	1.65£	0.75	47.4	1.12º	0.23	93.3	0.58¢	0.76	29.2
Waha	1.22£	84	10.7	0.92	0.84	12.3	1.11º	0.60	34.9	1.43£	0.84	118.0
Derraa	1.40£	75	23.5	1.75£	0.79	54.5	1.37£	0.62	52.2	1.03º	0.76	189.5
Hmho	1.29£	76	11.7	1.32£	0.89	24.2	1.37£	0.62	49.2	1.11º	0.73	80.5
Heider	0.75¢	74	5.7	0.88º	0.89	10.8	2.06£	0.70	103.9	0.98º	0.98	47.0
Mbb	0.75¢	77	6.2	0.55¢	0.72	9.0	1.38£	0.56	57.1	1.08º	0.84	67.0
Beliouni	0.94º	76	7.1	0.75¢	0.78	10.1	0.97º	0.48	33.9	0.80º	0.82	37.9

S2 * = X 103, S2 ** = x106, b¢ 1, bø = not significantly different from 0

Variation of the output grain is thus closely related to the expression of the number of grains m², the index of harvest and the weight of 1000 grains. The stability of the output is thus dependent on those of these three variables.

The stability of the output is approached by calculation of the coefficient of regression of Finlay and Wilkinson [1]) and by the variance off seasons [3]. A stable genotype is that which has a coefficient of regression equal to the unit and a weak variance inter-seasons. The required genotype is that which has ab = 1, a weak variance inter-countryside and an output grain higher than the general average of all the evaluated genotypes.

The coefficients of determination of the output, the number of grains m² and the index of harvest are higher 70% for the whole of the varieties except that of the Massara1 genotype which is very low. This indicates that the variation of the characters of this variety does not find a share important of explanation in the variation of the index of the medium. The coefficients of determination of the weight of 1000 grains are rather low suggesting that the variation of this character always does not follow that induced by the environment (Table 4).

The coefficient of regression of the output grain varies from 0.28 for Massara1 (not significantly differ from zero) to 1.40 for Derraa. Ads, Waha, Derraa and Heider/Martes//Huevos of oro are characterized by a b significantly higher than the unit. Mrb5, Heider and Mbb have a b significantly lower than 1. Cyprus and Beliouni have a coefficient of regression not significantly differ from the unit (Table 4).

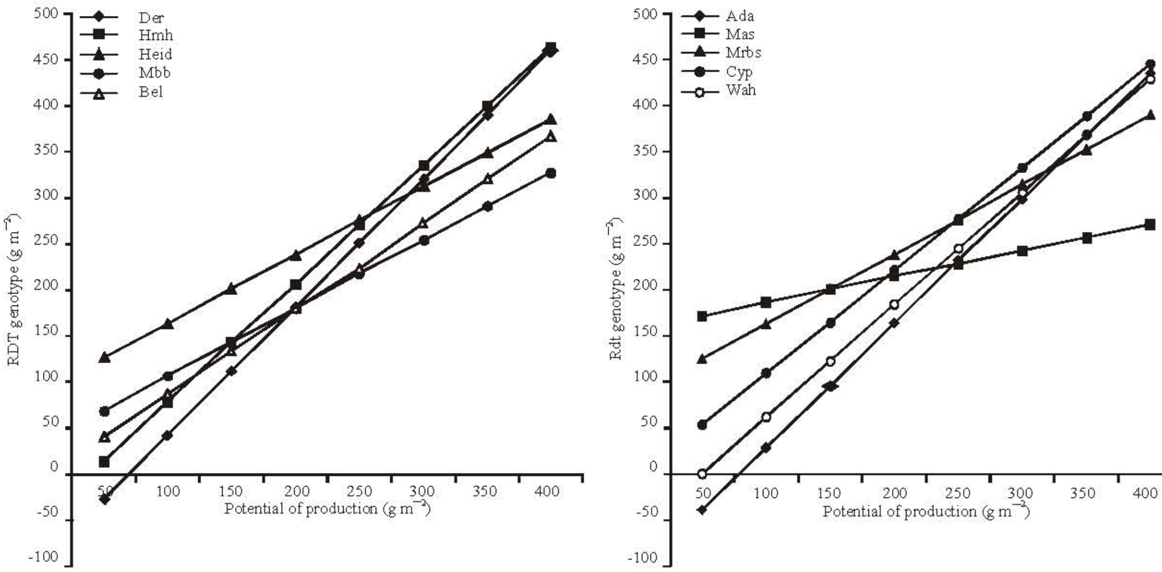

Fig. 2: Response of the output grain of the various genotypes to the variation of the potential of production of the seasons

The variance inter-season, weakest in value, is observed at Massara1 for the character output grain. Intermediate variances characterize the output grain of Heider, Mbb and Beliouni, whereas Cyprus1 and Derraa present strong variances inter-season (Table 4). The Tau coefficient of correlation of row of kendall indicates that the genotypic averages of the output grain are related on the variances inter-season and the coefficients of regression of the output grain ($Yi./S^2 = 0.662$, $Yi./b = 0.624$).

The coefficients genotypic of regression of the output are related to the variances inter-season ($b\ S^{-2} = 0.757$). The statistical parameters of the output (b and S^2) are also significantly correlated with those of the number of grains m^2 and the index of harvest ($b_{RDT}/b_{NGM2} = 0.75$, $b_{RDT}/S^2_{HI} = 0.67$, $S^2_{RDT}/b_{NGM}{}^2 = 0.93$, $S^2_{RDT}/S^2_{NGM}{}^2 = 0.95$, $S^2_{RDT}/S^2_{HI} = 0.66$). Among the evaluated genotypes Cyprus1 presents an average of output higher than the general average, a coefficient of regression b = 1 and one variance inter-season 7.5 times higher than that of Massara1, the most stable variety from the S^2 statistics (Table 4).

The coefficient of correlation of row between the coefficients of regression of the number of grains m^2 and the weight of 1000 grains is of negative sign ($b_{NGM}{}^2/b_{PMG} = -0.83$) suggesting that the increase in the one is often done with the detriment of the other (effect of compensation). Moreover the variation of the weight of 1000 grains measured by b and S^2 remains independent of that of the output grain, since the coefficients of correlation of row between the statistics of these variables are no significant.

Comparatively with the behavior of the cultivars Mbb, the genotypes Heider, Mrb5 and Cyprus1 are shown more productive on all the extent of the scale representing the potentialities of the medium of production (Fig. 2).

Heider and Mrb5 have a very similar behavior whereas Cyprus1 becomes increasingly productive as the medium becomes more fertile. The Massara1 variety represents a particular case of point of sight stability of the output grain in time (Fig. 2).

Massara1 develops the favorable mediums little, but it keeps a remarkable output in the constraining mediums where it manages to make an output unequalled grain by the other genotypes (Fig. 2). such genotypes according to Simane *et al.* [4] are tolerant with the stresses and they adapt thanks to their plasticity of behavior to various constraining situations. The plasticity of behavior is related to several phenomena of order phonologic, morphological, physiological and biochemical [5-7].

The regression of the weight of 1000 grains of each genotype on the number of grains m^2 produced during six campaigns shows that the reduction of the weight of 1000 grains, induced by the increase in a number of grains m^2, is genotype dependent. For an increase in the average of the number of grains m^2 of 1000 grains, Massara1, Mrb5, Heider, Mbb and Beliouni reduce the weight of 1000

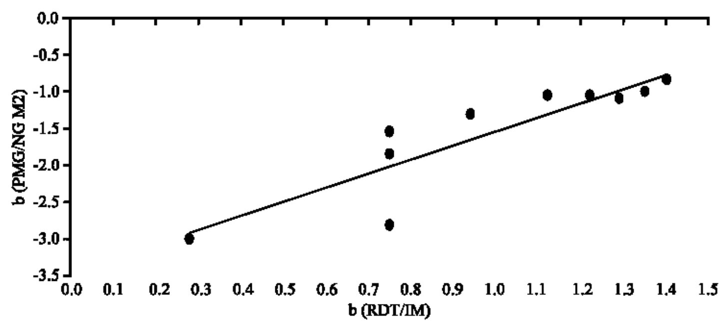

Fig. 3: Relation between the coefficients of regression of the output grain on the index of the medium and that of the weight of 1000 grains on the number of grains m^2

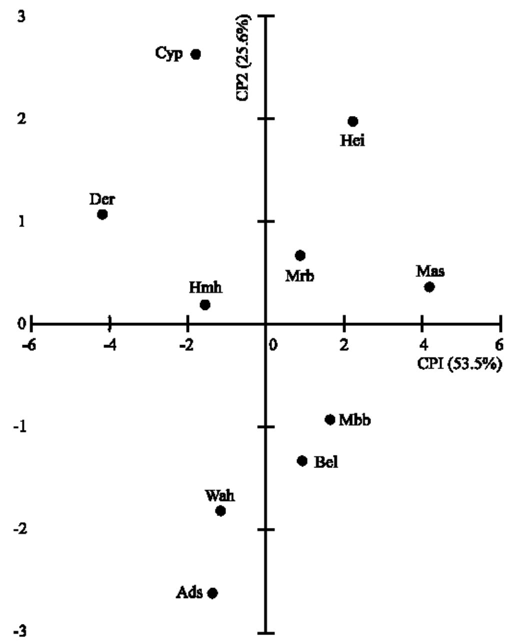

Fig. 4: Representation of the variables and the individuals in the field of axes 1 and 2 of the ACP STATE

grains by a factor -2.98, -1.55, -2.80, -1.83 and -1.30 g day^{-1} respectively.

The weight of 1000 grains is tiny room at Ads497, Cyprus1, Waha and Heider/Martes/Huevos de Oro by a factor of -1.01, -1.06, -1.06 and -1.09 g, respectively. Derraa is the variety which makes play less the effect of compensation between these two components with a reduction by -0.84 g of the weight of 1000 grains for an increase of a thousand of the number of grains m^2.

The coefficients of row between b and S^2 of the output with the coefficient of regression of the weight of 1000 grains on the number of grains m^2 is positive and significant ($\tau\ b_{RDT}/b_{PMG\text{-}NGM2}$ = 0.890 and $\tau S^2_{RDT}/b_{PMG\text{-}NGM2}$ = 0.749). These coefficients indicate that, under constraining conditions, when the genotype does not manage to produce a high number of grains m^2, it compensates for by an increase in the weight of 1000 grains (Fig. 3). the degree of this compensation, to minimize fall of the output grain, is variable according to genotypes.

The correlation between the genotypic averages of the weight of 1000 grains and the coefficient of regression of the weight of 1000 grains on the number of grains m^2 is significant and of sign negative ($\tau PMG/b_{PMG\text{-}NGM2}$ = -0.681). It indicates that the genotypes which significantly use the weight of 1000 grains to compensate for the reduction of the number of grains m^2 induced by the stress are the genotypes with high PMG (coarse grains).

For better visualizing the existing relations enter the genotypic answers for these variables (RDT, NGM^2, HI and PMG) and the average output of the six campaigns by genotype, we had recourse to analyze in principal components (Fig. 4). The plan formed by axes 1 and 2 explains 79.1% of information available in the variables subjected to the analysis.

Axis 1 manages information relating to the variation of the output and of the number of grains m^2 axis 2 manages, on the other hand, information relating to the variation of the weight of 1000 grains and the response of the index of harvest to the variation of the medium. These two characteristics are opposed along the axis (Fig. 4). In measurement or the two axes are not correlated, these results confirm that the variation of the PMG is partially independent of that of the output grain.

Along axis 1 are opposed Massara1 and Derraa. Massara1 is relatively more stable for the output and the number of grains m^2. Conversely Derraa is most irregular. Heider/Martes//Huevos de Oro and Mrb5, located close to the point of origin, thus have an intermediate stability for the output and the number of grains m^2 This axis indicates that the stability, synonymous with adaptation, is negatively correlated with the realization of a high output grain, in particular at Derraa, Heider/Martes//Huevos de Oro, Mrb5 and Massara1.

The characters taken charges some by axis 1 do not discriminate between the six genotypes remaining which are rather related to axis 2. Cyprus and Heider are opposed along this axis to Waha, Ads497, Mbb and Beliouni (Fig. 4). Cyprus1 and Heider is characterized by a high variation of the weight of 1000 grains, contrary to Waha, Ads497, Mbb and Beliouni. From share their position on the level formed by axes 1 and 2, Waha and Ads497 are characterized by a better distribution from the dry matter (HI).

This their confers the capacity to give high outputs comparatively to Mbb and Beliouni which tend to give poor yield grain (Fig. 4). Waha and Ads497 are relatively less stable (stability measured by the unit of the variables subjected to the ACP STATE and not only by the coefficient of regression), whereas Mbb and Beliouni are it more. Cyprus1 is more productive and less stable comparatively in Heider which is less productive and more stable (Fig. 4).

These results show that the stability of output is a very complex characteristic, dependent on several other variables like the east the output grain itself. In this case, it is negatively correlated with the productivity estimated by the output grain. It also related to the stability of the weight of 1000 grains and the number of grains m^2 the instability of the output grain can have various origins.

A strong sensitivity to the stress led to a null output, whereas a genotypic response to the fertility of the medium led to an output higher than awaited. A genotype which answers favorable to the improvement of the conditions of production is desirable for little that it manages to avoid the null output under stress. The strong compensation between the number of grains per ear and the number of ears which materializes in period of pre-anthese fact that the response of the number of grains per ear to these stresses is very variable [8].

CONCLUSIONS

The stresses most common to the semi-arid zones are the hydrous deficit, the thermal stress and radiation. These stresses generally intervene in interaction, especially at the time of the period of filling of the grain. The individual weight of the grain and the number of grains per ear component are affected by these stresses during this period.

The forecast of the variety show behavior on a scale of variation of the outputs of the similar medium to those observed during studied seasons, indicates that the genotypes with a $b>1$ are very risky at the time of the years unfavorable to the expression of the output.

Such genotypes lose their output to potentialities of production of the medium where other genotypes, in particular those with a $b = 1$ and especially those having a $b<1$) however take again the advantage of the output in the favorable environments.

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