Egypt. J. Plant Breed 9(2): 121-138 (2005)

SELECTION OF WHEAT LINES FOR YIELD AND LEAF RUST RESISTANCE

A.A. Abdel-Sattar [1], Nabila A., Mostafa[2] and I.A. Imbaby[3]

1- Genetics and Cytology Department, National Research Center, Cairo, Egypt
2- Barley Disease Section, Plant Pathol. Res. Institute ARC, Giza, Egypt.
3- Wheat Disease Section, Plant Pathol. Res. Institute ARC, Giza, Egypt.

ABSTRACT

The present study was conducted at the Agricultural Experimental Station of the National Research Centre, at Shalakan, Kalubia Governorate in 2000/2001 and 2001/2002 seasons to evaluate fifteen wheat breeding lines at F_4 and F_5 generations for yield and leaf rust resistance under field and greenhouse conditions. The cultivar Giza 160 was included as a check. Results showed significant differences among lines in all studied traits in both F_4 and F_5 generations except 1000-grain weight at F5 generation. Heritability estimates were high for all traits under field and greenhouse conditions. Grain yield/plant was positively correlated with other studied traits at both genotypic and phenotypic level the two generations under field conditions. A desirable negative correlation was found between both of incubation period on adult and latent period on adult with AUDPC, rust severity and No. of pustules/cm^2 on adult. Path-coefficient analysis revealed that 1000-grain weight, number of grains/spike and grain yield/spike followed by their joint effect were the highest contributors to variation in yield directly or indirectly. Three lines were considered as promising lines because of high yield and leaf rust resistance under field and greenhouse conditions.

Key words: ***Wheat, Grain Yield, Leaf Rust Resistance, Heritability, Path-Analysis***

INTRODUCTION

Wheat (*Triticum aestivum* L. subsp. *aestivum*) is one of the major cereal crops grown in Egypt. It is a stable food for the Egyptian peoples, therefore, it is grown on 2.5 million feddans in different agroecological regions to meet the ever- increasing domestic requirements.

Wheat is attacked by three rust diseases i.e strip rust caused by *Puccinia striiformis*, leaf rust caused by *P. triticina*, and stem rust caused by *P. graminis*. The most yield and quality- reducing rust of this crop worldwide is the leaf rust disease. Thus grain yield and yield stability based on resistance to the important rust diseases are the basic concepts of any breeding program of wheat.

Thus, an important goal in wheat breeding is the development of disease–resistant cultivars. Wheat breeders have historically favored a specific resistance, which is qualitative and cane be readily described by various coding schemes (Browder and Young 1975). Such codes permit rapid evaluation of a great number of entries. Specific resistance generally result in death of host cells and pathogens (Skipp *et al* 1974), although sporulation may occur before cessation of pathogen development.

Plant breeders have become interested in uniform resistance, which is quantitative rather than qualitative. Uniform resistance is characterized by one or more of the following: increased latent period, decreased spore production, decreased infection period, decreased infection efficiency, and decreased lesion size (Vanderplank 1963). Slow rusting cultivars allow the pathogen to develop, but at a much reduced rate. *Puccinia triticina* exihibts a longer latent period (Kuhn *et al* 1978 and Shaner 1983), smaller colonies, and smaller uredinia (Johnson and Wilcoxson 1978) on slow rusting wheat cultivars than fast rusting (susceptible) cultivars.

On the other hand, rust pathogens can mutate to overcome the existing resistant genes. Therefore, breeding for rust resistance needs to focus on maintaining current or higher levels of resistance and on developing new and improved sources of resistance. The maintenance of rust resistance involves a continuing search for and development of, new forms or combinations of resistance, to ensure that the varieties in farmer's fields have effective genetic resistance against the current strains of the pathogens. The objectives of this study were to (I) were to evaluate wheat lines for yield and leaf rust resistance under field and greenhouse conditions. (II) evaluate associations between yield components with grain yield (III) identify the most contributing characters which could be used as selection criteria in wheat improvement programmers using the path-coefficient analysis under rust infection conditions.

MATERIALS AND METHODS

The materials used traced back to a diallel cross set involving six bread wheat parents of divergent origin (Table 1). F_1 crosses were evaluated in 1997/98 season under two contrasting environments, normal conditions in Shalakan, Kalubia Governorate and saline conditions in Ras Sudr, South West of Saini (Afia and Abdel- Sattar 1998). F_2 segregates were evaluated in 1998/99 season using a randomized complete block design (RCPD) with three replications. 90 F_3 families derived from fifteen F_2 diallel cross were sown in randomized complete block design with three replications. Each family was represented by one row 3m long, 30 cm apart and approximately 7.5 cm between plants (40 plants per row). Seeds of the best 15 F_4 lines were saved based on grain yield and one or more of its attributes from all F_4 families divided in two parts.

Table 1.The names, source, pedigree and selection history of six parental varieties and/or lines under investigation.

Genotypes	Source	Pedigree and/or selection history
Line 1	ICARDA	Tsi/Vee"s" CM 64335-3AP-IAP-4AP-0AP
Line 2	ICARDA	Beh"s/4/PI ICW79-0628-2AP-2AP-1AP-0AP
Line 3	ICARDA	Maya 74"s"/On.CM58924-IAP-4AP-IAP-1AP-0AP
Sids 1	Egypt	HD2172/Pavon"s"//115857/Maya74"s",SD46-4SD-ISD-0SD.
Sakha 8	Egypt	Indus66/Norteno"s"-PK3418-6S-ISW-OS
Giza 162	Egypt	Vem/C no.67"s"/7c/3/Kat/Bh ('M8290D-4M-3M4Y4M.

The first part used for disease testing in greenhouse and the second part was sown with the check variety (Giza 160) on 28 Nov. 2000 in RCBD with three replications. The experimental plot area (7.5 m^2) consisted of eight rows, 3m long sown at a rate of 40 grains/ row.

Under field conditions, artificial rust inoculation for F_4 (2000/2001), and F_5 generation plants (2001/2002), was carried out at pre booting using a mixture of urediniospores of leaf rust with talcum powder (1:20 v/v) (Large, 1954) by the dusting method. Rust inoculations of the spreaders and the check Giza 160 were carried out by the hypodermic syringe method using aqueous urediniospores suspension to which 1 to 2 drops of Tween 20 were added, to break the surface tension.

Observations on response and severity of leaf rust was recorded according to Loegering (1959). The severity was recorded as percent of rust infection on the plants according to the modified Cobb scale (Peterson *et al* 1948). Readings of severity and reaction were recorded together with severity first. TR= Trace severity of resistant type infection, 10 MR = 10 percent severity of a moderately resistant type infection, and 50S= 50 percent severity of a susceptible type infection.

The Coefficient of Infection (CI) was calculated by multiplying the response value with the intensity of infection in percent. Average Coefficient of Infection (ACI) was derived from the sum of CI values of each entry (Table 2).

Table 2. The observation on response of leaf rust.

Reaction	Observation	Response value
No disease	0	0.0
Resistant	R	0.2
Moderately resistant	MR	0.4
Moderately susceptible	MS	0.6
Susceptible	S	1.0
Mesothetic	X	0.9

Recommended cultural practices for wheat were applied. At harvest, ten competitive plants from each plot were selected randomly to record observations on grain yield per plant, plant height, number of spikelets/ spike, spike length, number of grains/spikes, 1000- Kernel weight and grain yield/ spike. Similar procedures were repeated with F_5 lines in 2001/2002 season. The field work was conducted during successive seasons (1998/ 1999 to 2001/2002) at the Agricultural Experimental Station of the National Center , at Shalakan, Kalubia Governorate.

Five plant sets were grown in 50 cm diameter pots for 75 days. At growth stage 10(booting stage, Large 1954), plants were inoculated with a mixture of *P. triticina* races mixed with talcum powder (1:20 v/v), incubated in a humid chamber for 24 hrs. and then transferred onto greenhouse benches at 20°C.

Incubation period and latent period

At flecking time, the plants were checked to record the first pustule erupted to estimate the incubation period. After that, the plants were daily inspected until 50% erupted pustules were obtained to estimate the latent period.

Area under progress curve (AUDPC)

Also, area under disease progress curve was estimated using the following equation:

$$\sum_{i-1}^{n} = [(Y_{i-1} + Y_i)/2] [X_{i-1} - X_i]$$

Where:

Yi= rust severity at the i^{th} observation.

Xi = time (days)at the i^{th} observation.

n= total no. of observations.

Mean performance and selection index were performed as described by Smith (1936) and applied by Tallis (1962). Broad sense heritability was estimated according to Robinson *et al* (1951). Phenotypic and genotypic correlation coefficients were computed according to Steel and Torrie (1980). Path coefficient analysis was performed according to Dewey and Lu (1959) as illustrated by Singh and Chaudhary (1985) to partition the phenotypic correlation between characters into direct and indirect effects.

RESULTS AND DISCUSSION

Data in Table (3) showed that severe leaf rust infections were developed on genotypes nos. 1,5,7,13,14, and 15 in F_4 or F_5 generations. On the other hand, genotypes no. 4, 9, 10, and 11showed intermediate reaction to leaf rust. Other genotypes (2, 3, 6, 8, and 12), showed low level of infection under field conditions (Table 3). These genotypes were selected and evaluated under greenhouse conditions in F_5 generation and showed also low level of infection Table (4).

Table 3. Average coefficient of infection (ACI) of leaf rust in F_4 and F_5 generations wheat lines under field conditions in 2000/2001 and 2001/2002 growing season.

Line	ACI /season		
	F_4 generation (2000/2001)	F_5 generation (2001/2002)	Mean
1	80	100	90
2	30	20	25
3	20	6	13
4	12	6	41
5	60	80	70
6	12	40	26
7	80	60	70
8	10	30	20
9	12	6	9
10	20	50	35
11	10	30	20
12	30	6	18
13	70	50	60
14	70	40	55
15	70	60	65
Giza 160	80	100	90

Table 4. Selected F_5 genotypes with low coefficient ACI for leaf rust and area under progress curve under greenhouse conditions.

Genotype	Mean ACI	AUDPC
2	15	655.27
3	13.13	399.81
6	15.55	548.28
8	17.22	725.24
12	2.22	173.04
Giza 160	18.33	974.09

Analysis of variance

The analysis of variance (Table 5) showed highly significant differences among genotypes at both generations for all the characters considered, except 1000 – grain weight at F_5 generation. The variability among F_4 lines was higher than that of F_5 lines as reflected by values of mean squares for all studied traits. Moreover, the analysis of variance for the five slow rusting components at adult stage in greenhouse is shown in Table (6). Mean squares for genotypes were highly significant for all studied traits indicating genotypic variability for these traits. These results indicated that certain genotypes carry alleles with different additive

and additive x additive effects. Wide and significant differences among the promising bread wheat genotypes for various traits under rust infection were observed (as shown in Tables 5 and 6) revealing that variability existed among genotypes which increased the chance of selecting more leaf rust tolerant genotypes. This agreed with El-Marakby *et al* 1994, Afiah and Abdel-Sattar (1998), Ismail (2001) and Khattab (2003).

Performance and selection index

The selection index which has been illustrated by Smith (1936) gives proper weight to each of two or more characters to be considered for selecting better genotypes. When the economic importance of plant type is considered , thus the entry with the highest yield may not get the highest score resulting from use of the selection index (Robinson *et al* 1951). Selection index based on a combination of seven major characters were studied. The 15 genotypes and check variety Giza 160 in the two generations under leaf rust infection conditions in field were descending ranked (Table 7). Results revealed that, the best five selected genotypes as detected by general selection criterion among 16 ones in the two generations were 8, 9, 12, 3 and 1. Regarding to (Table 7). It is worthy to mention that, these genotypes were the highest in grain yield/plant, number of grains/spike and 1000-grain weight. These characters showed the highest values (0.53 and 0.55, respectively) for direct effect of these characters on yield per plant as detected by path analysis in two generation (Table 11). Moreover, these characters revealed highly significant and positive correlations between each of them and grain yield/ plant in two generations (Table 9). Furthermore, number of grains/ spike and 1000- kernel weight were the most important factors contributing to plant yield in two generations (Table 10). The 5 best genotype and check variety Giza 160 based on the results were arranged descendly according to classical selection index in Table (8). The three genotypes 8,12 and 3 were the best

Table 5. Mean squares for grain yield and its components of wheat genotypes from F_4 and F_5 generations under leaf rust infection conditions in field.

S.O.V.	d.f	Grain yield/plot		Plant height		No. of spikelets /spike		Spike length		No. of grains/ spike		1000-grain weight		Grain yield/ spike	
		F_4	F_5	F_4	F_5	F_4	F_5	F_4	F_5	F_4	F_5	F_4	F_5	F_4	F_5
Genotypes	15	3.37**	2.76**	193.19**	151.57**	17.87**	11.82**	5.45**	5.68**	139.09	112.43**	2.44**	2.71	0.74**	0.78
Error	30	4.05	0.14	14.77	22.49	2.25	3.09	0.63	0.54	13.56	6.10	0.[illegible]1	0.06	0.02	0.04

*,** significant at 0.05 and 0.01 levels of probability, respectively.

Table 6: Mean square for leaf rust severity and slow rusting components at adult stages for the five selected genotypes of the F_5 generation.

Source of variation	d.f	Rust severity	Incubation period	Latent period	No. of pustules/cm^2	AUDPC
Genotypes	5	662.49**	5.03**	17.73**	78.06**	131802.40**
Errors	10	6.22	0.41	2.43	127.72	1293.46

** Significant at 0.01% levels of probability.

Table 7. The 15 bread wheat genotypes and the check variety Giza 160 arranged descendly according to selection index values and their corresponding means for yield and its components at F_4 and F_5 generations under leaf rust infection conditions in field.

Genotypes		Grain yield/plot	Plant height	No. of spiklets/ spike	Spike length	No of grains/ spike	1000-grain weight	Grain yield/ spike
F_4								
8		5.97	101.67	23.00	10.70	63.67	40.57	2.90
9		4.97	104.00	26.00	14.00	55.33	30.83	2.10
12		5.27	113.33	17.67	9.17	44.67	60.47	2.93
3		3.97	106.00	24.00	11.27	54.67	30.63	1.97
1		3.36	106.00	19.33	10.10	51.66	30.90	2.00
13		3.33	106.33	18.67	10.77	48.33	30.47	1.67
10		2.43	103.67	20.00	11.60	49.33	30.03	1.50
7		2.80	101.33	23.33	11.60	39.00	40.33	1.67
6		3.53	86.33	22.00	11.16	57.33	30.33	1.90
15		2.97	98.00	21.33	12.03	48.67	20.93	1.43
Giza 160		2.53	92.67	21.67	11.77	49.00	30.00	1.63
4		2.73	104.67	19.00	9.27	42.33	30.80	1.60
5		3.63	84.33	23.33	11.53	53.00	20.80	1.40
11		2.30	109.67	19.33	9.90	40.33	20.90	1.17
14		3.13	96.33	19.33	10.10	46.33	30.33	1.53
2		3.07	94.[illegible]7	18.00	8.43	40.67	30.70	1.50
L.S.D	0.05	0.52	6.41	2.49	1.33	6.14	5.4	0.22
	0.01	0.70	8.63	3.36	1.78	8.26	7.3	0.30
F_5								
8		5.90	101.67	23.67	11.07	60.00	40.87	3.10
9		4.87	105.00	24.67	14.13	54.00	30.97	2.23
12		5.27	115.33	18.67	9.10	43.67	60.83	3.47
3		4.07	107.67	25.00	11.50	56.33	40.03	2.10
1		3.63	103.67	20.67	10.47	51.67	30.93	2.20
15		3.23	102.33	22.33	12.83	46.33	30.03	1.90
13		3.83	107.00	19.67	11.40	46.33	30.63	1.90
6		3.70	90.33	21.67	11.50	57.00	30.53	2.03
7		2.93	102.00	22.00	12.20	42.33	40.30	1.80
10		2.43	103.33	20.67	11.73	49.33	30.10	1.77
5		3.63	89.33	23.33	12.10	51.00	20.90	1.67
Giza 160		2.73	94.33	21.33	11.60	48.67	30.23	1.83
4		2.87	106.00	19.67	9.63	43.00	40.10	1.83
11		2.73	112.33	20.00	9.87	40.33	30.13	1.67
14		3.30	98.33	19.67	11.07	44.67	30.47	1.80
2		3.10	97.67	19.00	8.87	40.33	30.90	1.73
L.S.D	0.05	0.62	7.91	8.93	1.23	4.12	4.2	0.34
	0.01	0.84	10.65	3.95	1.66	5.54	5.7	0.46

Table 8. Means performance of the slow rust components of the five selected genotypes of F_5 generation at adult plant stages in descending order under greenhouse conditions.

Genotypes		Rust severity	Incubation period	Latent period	No. of pustules/cm2	AUDPC
12		10.92	9.56	17.26	24.39	139.89
6		20.92	7.89	15.77	37.07	285.83
3		31.85	6.56	12.11	47.55	435.61
8		38.74	6.22	11.33	53.82	538.61
2		42.77	6.56	13.38	53.63	558.05
Giza 160		51.48	6.44	11.59	71.61	727.22
LSD	0.05	4.54	1.17	2.83	20.56	65.43
	0.01	6.46	1.66	4.03	29.24	93.06

for slow rusting components traits and it the same time for yield and its components Ohm and Shener (1976) reported that slow-rusting resistance to leaf rust was reduced after flowering but nevertheless, suggested that serious yield losses should be prevented by the delayed progress of the disease during sensitive host growth stages. Genotypes which gave the highest values for yield and yield components and resistance to leaf rust had the best ability yield under leaf rust infection in field conditions and therefore could be used in improving yield and its components under leaf rust infection conditions in the field.

Heritability

Heritability estimates under leaf rust infection conditions in the field at two generations (Tables 9) and for five slow rusting components at adult stage at F_5 generation under greenhouse condition (Table 10) were generally high for all studied traits except number of spikelets/ spike in F_5 generation which have moderate heritability value. These results indicated that, the environment had a small effect on the inheritance of such characters at the two generations. High heritability estimates for all studied traits indicated that selection based on mean performance would be successful in improving these traits. Where a trait shows high heritability and a good association with performance, it might lend itself to early generation selection, instead of or in addition to selection in yield traits. Even for a trait relatively weakly associated with performance, but highly heritable, early generation selection may be a useful tool for eliminating the poorest material. The genetic system controlling these traits might be attributed to additive effects of genes.

Correlations

Genotypic and phenotypic correlations were computed in both F_4 and F_5 generations among certain characters of bread wheat as affected by leaf rust infection in field (Table 9). In most cases, both phenotypic and genotypic correlation coefficients among the studied traits agreed in sign. In those cases where the magnitude of the phenotypic and genotypic correlation coefficients were nearly the same, the environmental variance and covariance had been reduced to zero or to a negligible level, i.e., the influence of environment on these relationships was minimal (Sidwell *et al* 1976). Grain yield/plant was highly significantly correlated with each of number of grains/spike, 1000-grain weight and yield/spike and positively correlated for plant height, number of spikelets/spike and spike length at both genotypic and phenotypic levels in both generations. A knowledge of the correlations that exit between important characters may facilitate the interpretation of results already obtained and provide the basis for planning.

Table 9. Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlation and heritability (diagonal) among all studied traits in the F_4 and F_5 generations under leaf rust infection in the field.

Characters of yield components	Grain yield/ plant	Plant height	No. of spikelets/ spike	Spike length	No. of grains/ main spike	1000 grain weight	Yield/ spike
			F_4				
Grain yield/ plant	0.918	0.180	0.358	0.117	0.654**	0.695**	0.920**
Plant height	0.197	0.801	-0.324	-0.216	-0.300	0.568*	0.365
No. of spikelets/ spike	0.286	-0.260	0.699	0.891**	0.668**	-0.198	0.146
Spike length	0.120	-0.198	0.742**	0.718	0.569*	-0.366	0.047
No. of grains / main spike	0.587	-192	0.414	0.314	0.755	0.002	0.519*
1000 grain weight	0.596	0.4444	-0.167	-0.266	-0.113	0.879	0.849**
Yield/ spike	0.854	0.306	0.070	-0.056	0.465	0.810**	0.929
			F_5				
Grain yield/ plant	0.863	0.254	0.447	0.078	0.580*	0.708**	0.927**
Plant height	0.200	0.657	-0.307	-0.309	-0.358	0.591*	0.489*
No. of spikelets/ spike	0.257	-0.149	0.484	0.929**	0.929**	-0.186	0.075
Spike length	0.062	-0.284	0.516*	0.758	0.519*	-0.446	-0.224
No. of grains / main spike	0.502*	-0.235	0.513*	0.384	0.853	-0.003	0.353
1000 grain weight	0.619**	0.439	-0.185	-0.356	-0.031	0.932	0.901**
Yield/ spike	0.754**	0.306	0.015	-0.174	0.311	0.838**	0.855

Table 10. Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlations and heritability (diagonal) among slow rusting components at adult stage under greenhouse conditions.

Characters of slow rusting components	AUDPC on adult	Rust Severity on adult	No. of pustules/cm^2 On adult	Incubation period on adult	Latent period on adult
AUDPC on adult	0.971	0.998**	0.996**	-0.919**	-0.947**
Rust severity on adult	0.996**	0.972	0.989*	-0.922**	-0.932**
No. of pustules/cm^2 on adult	0.888*	0.877*	0.630	-0.896*	-0.994**
Incubation period on adult	-0.826*	-0.832*	-0.818*	0.790	0.992*
Latent period on adult	-0.789	-0.784	-0.672	0.814*	0.678

more efficient programs for the future. Also, correlations between important and non-important characters may reveal that some of the latter are useful as indicators of one or more of the former (Herbert *et al* 1955). Moreover, number of spikelets/spike was significantly positively correlated with spike length at both genotypic and phenotypic levels in both generations and number of grains/ spike in genotypic correlation in F_5 generation. Furthermore, 1000- grain weight was significantly positively correlated with yield/spike at both genotypic and phenotypic levels in both generations. Meanwhile, number of grains/spike showed significant and positive genotypic correlation with yield/ spike in F_4 generation and with spike length in F_5 generation. Spike length showed significant and positive genetic correlation with number of grains/spike in F_4 generation. Other correlations were nonsignificant. Genotypic and phenotypic correlations for five slow rusting components under green house condition are presented in Table

(10). The results demonstrate that estimates of genotypic correlation coefficients were generally higher than their corresponding phenotypic correlation coefficients and both of them agreed in sign. Highly significant and positive correlations were detected between AUDPC and rust severity on adult plants and number of pustules/cm^2 on adult at both genotypic and phenotypic levels. Significant negative correlation was found between both of incubation period on adult and latent period on adult with AUDPC, rust severity and No. of pustules/cm^2 on adult. Van der Plank (1988) reported that slow leaf rusting wheats interfere with pathogensis by *P.recondite* by lengthening the latent period and reducing the number of spores produced. Yu-Guzhov (1984) reported that, when a close correlation is found within one or another pair of characters, the breeder has a particularly equal choice of selection based on any of them, however, it is better to use the correlated character that lends itself more readily to measurement. Falconer (1989) indicated that if two traits are associated selection pressure should be applied to the trait easier to asses and select. Moreover, the relationship between grain yield/plant and its components is of considerable value to breeders for screening breeding material. Similar results were reported by Fonseca and Patterson (1968), Esmail (2001) and Ismail (2001).

Path coefficient analysis

Further information on the association among characters were obtained by the path coefficient analysis, which involves partitioning the phenotypic and genotypic correltion coefficients into direct and indirect effects via alternative characters or pathways. The direct and indirect effects of the six yield- related traits in F_4 and F_5 generations at the phenotypic level under leaf rust infection in field are shown in Table (11).

Grain yield /plant was considered as a resultant variable and plant height, number of spikelet/spike, spike length, number of grains/spike, 1000 grain weight and grain yield/ spike as causal variables.

Results of path coefficients analysis at phenotypic level revealed that 1000-grain weight had the highest effect on grain yield/plant (0.5553 and 0.3892) followed by number of grains/spike (0.5343 and 0.3342) and grain yield/ spike (0.1262 and 0.3210) in the F_4 and F_5 generations, respectively. Singh and Chaudhary (1985) reported that if the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then correlation explains the true relationship and direct selection through this trait will be effective. In this study, for instance, the direct effect of 1000 grain- weight on grain/ plant (direct effect = 0.5553 and 0.3892 at F_4 and F_5 generations, respectively) accounted for the total correlation between

Table 11. Partitioning of simple correlations between yield/ plant and its components of bread wheat at phenotypic level in the F_4 and F_5 generations under leaf rust infection in the field.

Source	Phenotypic		Source	Phenotypic	
	F4	F5		F4	F5
Plant height VS. grain yield/plant			No of grains/ spike Vs. grain yield/plant		
Direct effect (PY1)	0.0569	0.0501	Direct effect (PY4)	0.5343	0.3342
Indirect effect via:			Indirect effect via:		
No. of spiklets/ spike	-0.0438	-0.0176	Plant height	-0.0109	-0.0118
Spike length	0.0014	-0.0231	No. of spikelets/ spike	0.0698	0.0607
No of grains/ spike	-0.1026	-0.0785	Spike length	-0.0022	0.0312
1000- grain weight	0.2465	0.1709	1000- grain weight	-0.0627	-0.0121
Grain yield/ spike	0.0386	0.0982	Grain yield/ spike	0.0587	0.0998
Total direct + indirect	0.1971	0.2000	Total direct + indirect	0.5869	0.5021
No. of spikelets/ spike VS. grain yield/plant			1000- grain weight Vs. grain yield/ spike		
Direct effect (PY2)	0.1685	0.1184	Direct effect (PY5)	0.5553	0.3892
Indirect effect via:			Indirect effect via:		
Plant height	-0.0148	-0.0075	Plant height	0.0253	0.0220
Spike length	-0.0051	0.0420	No. of spikelets/ spike	-0.0281	-0.0219
No of grains/ spike	0.2212	0.1714	Spike length	0.0018	-0.029
1000- grain weight	-0.0927	-0.0720	No of grains/ spike	-0.0604	-0.0104
Grain yield/ spike	0.0088	0.0048	Grain yield/ spike	0.1022	0.2690
Total direct + indirect	0.2859	0.2571	Total direct + indirect	0.5961	0.6190
Spike length Vs. Grain yield/ plant			Grain yield/ spike Vs. grain yield/plant		
Direct effect (PY3)	-0.0069	0.0813	Direct effect (PY6)	0.1262	0.3210
Indirect effect via:			Indirect effect via:		
Plant height	-0.0113	-0.0142	Plant height	0.0174	0.0153
No. of spikelets/ spike	0.1250	0.0611	No. of spikelets/ spike	0.0118	0.0018
No of grains/ spike	0.1678	0.1283	Spike length	0.0004	-0.0142
1000- grain weight	-0.1477	-0.1386	No of grains/ spike	0.2484	0.1039
Grain yield/ spike	-0.0071	-0.0559	1000- grain weight	0.4498	0.3262
Total direct + indirect	0.1199	0.0621	Total direct + indirect	0.8540	0.7541

them (r=0.5961 and 0.6190 in the same order, Table 9). Therefore, 1000-grain weight is the most important factor contributing positively to grain yield/plant. However, the correlation coefficient between grain yield/ plant with number of grains/ spike was positive and significant and the direct effects were positive and high or moderate in two generations. Furthermore, these results showed that 1000- grain weight, number of grains/spike and grain yield/ spike could be used as selection criteria in wheat under leaf rust infection conditions for adult plants in field. However, the indirect effect of 1000- grain weight on grain yield/ plant via number of grain/ spike was negative (-0.0604 and -0.0104) and via grain yield/spike was positive (0.1022 and 0.2690), the other indirect effects via plant height, number of spikelets/ spike and spike length were negligible or negative. The present results reflect the same picture of the phenotypic correlation shown earlier in Tables (4 and 5). Previous studies reported that, 1000-grain weight had positive direct effect on grain yield/ plant (Ibrahim 1994, Ismail 2001). Esmail (2001) reported that the grain weight/ spike had the highest direct effect on grain yield / plant.

Number of grain/ spike had the second important direct effect on grain yield/ plant in the two generations. Indirect effect via number of spikelets/ spike and grain yield/ spike were positive in both generations and spike length was positive in F_5 generation, while the indirect effect via plant height and 1000- grain weight in two generations and spike length in F_4 generation were negative.

Grain yield/ spike had the third important direct effect on grain yield/ plant. Indirect effect via all studied traits revealed positive values in two generations except for spike length in F_5 generation which showed negative values.

Number of spikelets/ spike ranked the fourth order in its positive direct effect on grain yield/ plant. Indirect effect was positive via number of grains/ spike. The remaining indirect effects were negative or negligible.

Positive direct effect was shown for plant height on grain yield/ plant in both generations. Indirect effects were positive via 1000- grain weight and grain yield/ spike in both generations, while number of grains/ spike in both generations and spike length in F_5 generation revealed negative values.

Negative direct effect was shown for spike length in grain yield/ plant in F_4 generation, while in F_5 generation a positive value was shown. Indirect effects were shown via number of spikelets/ spike and number of grains/ spike. Negative indirect effects were shown via 1000-grain and grain yield/ spike in both generations.

The importance of indirect selection could be considered in the absence or negligible values of direct effects. Also, indirect selection can only be effective if a correlation exists between these traits and the indirect character can be measured with more accuracy than the primary character (Wricke and Weber 1986). Our results are in harmony with those reported by El-Marakby *et al* (1994) and Esmail (2001).

The correlation coefficients recorded in Table (9) were then used in the path- coefficient analysis to detect the relative importance of each character to grain yield. The coefficients of determination were calculated for the direct and indirect effects of the six yield factors studied, transformed into percentages in order to evaluate these factors according to their importance as sources of variation in plant yield. Results presented in descending order in Table (12) revealed that the relative contribution of direct and joint effects for yield components were different concerning grain yield variation from generation to another. In F_4 generation, the main sources of grain yield variation in order of importance were the direct effect of 1000- grain weight (29.395%) followed by direct effect of number of grains/spike (27.22%) and their joint effect (6.388%) and the joint effect of 1000-grain weight with grain yield/ spike (10.82%), then joint effect of number of spikelets/spike with number of grains/ spike (7.1%), number of grains/spike with grain yield/ spike (5.98%), joint effect of number of spikelets/ spike with 1000- grain weight (2.98%), direct effect of spikelets/ spike (2.71%), joint effect of plant height with 1000-grain weight (2.68%), direct effect of grain yield/ spike (1.516%), joint effect of plant height with number of grains/ spike (1.116%). The total contribution of the six traits directly or jointly amounted to 99.991%, while the residual effect amounted to 0.009% of the total grain yield variation. In F_5 generation, the main sources of grain yield/ plant variation at phenotypic level were 1000-grain weight, number of grains/spike, grain yield/ spike, and their with remaining traits. The six studied traits and their interactions were responsible for (99.47%) of grain yield/ plant variation in phenotypic level. It could be concluded that, number of grains/ spike, 1000-grain weight and grain yield/ spike and their joint effect are considered the selection criteria that would be most dependable in improving grain yield under rust infection conditions for adult plants in field. Previous investigations by Fonseca and Patterson (1968) reported that kernels/ spike and kernels weight had large direct effects on grain yields. Assey *et al* (1979) reported that number of grains/ spike and 1000- grain weight had the greatest contribution to grain yield.

Table 12. Components (direct + joint effects) as percentage of different contribution to yield / plant and its components in bread wheat at phenotypic level in F_4 and F_5 generations under leaf rust infection in the field.

Source of variation	F_4		F_5	
	CD	RI%	CD	RI%
Plant height (x1)	0.0032	0.305	0.0025	0.300
No. of spikelets/ spike (x2)	0.0284	2.708	0.0140	1.167
Spike length (x3)	0.000	0.000	0.0066	0.792
No of grains/ spike (x4)	0.2855	27.222	0.1117	13.400
1000- grain weight (x5)	0.3083	29.395	0.1515	18.175
Grain yield/ spike (x6)	0.0159	1.516	0.1031	12.369
X1x X2	-0.0050	0.477	-0.0018	0.216
X3	0.0002	0.019	-0.0023	0.280
X4	-0.0117	1.116	-0.0079	0.948
X5	0.0281	2.679	0.0171	2.051
X6	0.0044	0.420	0.0098	1.176
X2 x X3	-0.0017	0.162	0.0099	1.188
X4	0.0745	7.103	0.0406	4.841
X5	-0.0313	2.984	-0.0170	2.039
X6	0.0030	0.286	0.0011	0.132
X3 x X4	-0.0023	0.219	-0.0209	2.507
X5	0.0020	0.191	-0.0225	2.700
X6	0.0001	0.001	-0.0091	1.092
X4 x X5	-0.0670	6.388	-0.0081	0.972
X6	0.0627	5.978	0.0667	8.001
X5 x X6	0.1135	10.822	0.2094	25.120
Residual	0.1891	0.009	0.3037	0.534
Total	1.0000	100.00	1.00000	100.00

CD= Coefficient of determination, RI= Relative importance.

Ibrahim (1994) reported that number of grains/spike and 1000-grain weight had the greatest effects on grain yield. Esmail (2001) reported that grain weight/spike had the highest contribution to grain yield, either through its direct effects and /or its indirect effects with other characters.

REFERENCES

Afiah, S.A.N. and A.A. Abdel-Sattar (1998). Diallel cross analysis for some quantitiative characters in bread wheat (*Triticum aestivum* L.) under saline and normal environments. Annals of Agric. Sci. Moshtohor 36(4): 2039-2061.

Assey, **A.A., E.M. Zeidan, A.G. Eraky and A.R. Al-Kaddoussi (1979).** Correlation and path coefficient analysis between yield and yield attributing components in wheat. Ann. of Agric. Sci. Moshtohor 12:95-103.

Browder, L.E., and H.C. Young (1975). Further development of an infection type coding system for the cereal rusts. Plant Dis. Rep. 59:964-965.

Dewey, D.R. and K.H. Iu (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. Agron. J. 51:515-518.

El-Marakby, A.M., M. Yasein, A.A. Mohamed and A.M. Tolba (1994). Correlation and path analysis for yield attributes in F_2 and F_3 segregating populations of five wheat crosses. Annals of Agric. Sci. Moshtohor 32: 1065-1072.

Esmail, R.M. (2001). Correlation and path coefficient analysis of some quantitative traits with grain yield in bread wheat (*Triticum aestivum* L.). Bull. NRC Egypt 26(3): 395-408.

Falconer, D.S. (1989). Introduction to quantitative genetics. 3rd ed. John Willey & Sons, New York.

Fonseca, S. and F.L. Patterson (1968). Yield component heritabilities and interrelationship in winter wheat (*Triticum aestivum* L.). Crop. Sci. 8: 614-617.

Herbert, W.J., H.F. Robinson and R.E. Comstock (1955). Genotypic and phenotypic correlations in soybean and their implications in selection. Agron. J. 47: 477-4 83.

Ibrahim, K.I.M. (1994). Association and path coefficient analysis of some traits in bread wheat. Annals of Agric. Sci. Moshtohor 32:1189-1198.

Ismail, A.A. (2001). Identification of selection traits for yield improvement of bread wheat using path analysis. Assiut J. of Agric. Sci. 32(1): 63-84.

Johnson,D.A., and R.D. Wilcoxson (1978). Components of slow-rusting in barley infected with *Puccinia hordi*. Phytopathology 68:1470-1474.

Khattab, S.A.M. (2003). Heterosis, combining ability and genetic variation for yield and yield contributes in wheat under northern coast condition. J. of Genetic Eng. & Biotechol. (NRC) 1(2): 394-407.

Kipp, R.A., D.E. Harder and D.J. Samborski (1974). Electron microscopy studies on infection of resistant (Sr6 gene) and susceptible wheat lines by *Puccinia recondita*. Can. J. Bot. 52: 2615-2620.

Kuhn, R.C., H.W. Ohm and G.E. Shaner (1978). Slow leaf –rusting resistance in wheat against twenty-two isolates of *Puccinia recondita*. Phytopathology 68: 651-656.

Large, E.C. (1954). Growth stages in cereals: Illustration of the Feekes scale. Plant Patholo. 3: 128-129.Loegering, W.Q.1959. Methods for recording cereal rust data. U. S. D. A. international spring wheat rust nursery.

Ohm H.W. and G.E. Shamer (1976). Three components of slow leaf-rusting at different growth stages of wheat. Pytopathology 66:1356-1360.

Peterson, R.F., **A.B. Capbell, and A.E. Hannah (1948).** A diagrammatic scale for estimating rust intensity of leaves and stem of cereals. Can J. Res.Sect. C 26: 496-500.

Robinson, H.R., R.E. Comstock and P.H. Harvey (1951). Genotypic and phenotypic correlation in corn and their implications to selection. Agron. J. 43:282-287.

Shaner, G. (1983). Growth of uredinia of *Puccinia recondita* in leaves of slow and fast- rusting cultivars. Phytopathology 73: 931-935.

Sidwell, R.J. E.L. Smith and R.W. Mcnew (1976). Inheritance and interrelationships of grain yield and selected yield-related traits in a hard red winter wheat cross. Crop Sci. 16:650-654.

Singh, R.K. and B.D. Chaudhary (1985). Biometrical methods in quantitative genetic analysis. Revised Edition, Kalani. Publishers, New Delhi, Ludhiana, India.

Smith, H.F. (1936). A discriminate function for plant selection. Ann. Fungenics. 7: 240-250.

Steel, R.G.D. and J.H. Torrie (1980). Principles and procedures of statistics. McGraw-Hill, New York.

Tallis, G.M. (1962). A selection index for optimum genotype. Biometrics. 18:120-122.

Van der plank, J.E. (1963). Plant Disease: Epidemics and control. Academic Press, New Yourk and London. 349 pp.

Van der plank J.E., (1982). Disease resistance in plants, New York: Academic 2nd ed.

Wricke, G. and E. Weber (1986). Quantitative genetics and selection in plant breeding. Walter de gruyter. Berlin. New York.

إنتخاب سلالات قمح للمحصول ومقاومة لصدأ الأوراق

[1]عبد الستار أحمد عبد الستار و [2]نبيلة أحمد مصطفى و [3]إبراهيم أحمد أمبابى

١- قسم الوراثة والسيتولوجى – المركز القومى للبحوث – القاهرة – مصر

٢- قسم بحوث أمراض الشعير – معهد بحوث أمراض النباتات – مركز البحوث الزراعية.

٣- قسم بحوث أمراض القمح– معهد بحوث أمراض النباتات – مركز البحوث الزراعية.

أقيمت تجربتان حقليتان بمحطة البحوث والتجارب الزراعية بالمركز القومى للبحوث بشلقان وذلك خلال مواسم ٢٠٠٠/٢٠٠١و ٢٠٠١/٢٠٠٢ لتقييم خمس عشرة سلالة مقارنة بالصنف التجارى جيزة ١٦٠ للمحصول ومقاومة مرض صدأ الأوراق فى القمح تحت ظروف الحقل وكذلك تحت ظروف الصوبة ودراسة الارتباط المظهرى والوراثى بين محصول الحبوب والصفات المساهمة فيه وكذلك تحليل معامل المرور لمعرفة التأثيرات المباشرة وغير المباشرة على المحصول وتحديد مساهمتها النسبية فيه. وفيما يلى ملخص لأهم النتائج المتحصل عليها.

- أظهرت النتائج وجود ارتباط موجب بين المحصول وكل الصفات المدروسة تحت مستوى الحقل وارتباط سالب ومفيد بين صفات فترة الكمون والحضانة مع شدة الإصابة وعدد البثرات/سم٢ والمساحة تحت منحنى تطور المرض.
- كانت درجة التوريث المحسوبة عالية القيمة لكل الصفات تحت الدراسة.
- كانت صفات وزن الـ ١٠٠٠ حبة وعدد الحبوب فى السنبلة ومحصول السنبلة والتأثير المشترك بينها أكثر الصفات التى يجب أن تحظى باهتمام المربى عند الانتخاب غير المباشر للمحصول تحت ظروف الإصابة بصدأ الأوراق فى الحقل حيث كانت أكثر الصفات مساهمة فى تباين المحصول.
- تشير نتائج الدراسة إلى تحديد ثلاث السلالات مبشرة يمكن إدخالها فى برامج التربية المستقبلية بهدف إنتاج أصناف جديدة عالية المحصول ومقاومة لمرض صدأ الأوراق فى القمح.