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SHORT NOTE

Associations among *Fusarium* wilt resistance, flower colour and number of flowers per fruiting node in chickpeas (*Cicer arietinum* L.)

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Corolla colour in chickpea (*Cicer arietinum* L.) is white or various shades of pink or blue (Smithson, Thompson & Summerfield, 1985). Normally, a leaf axil subtends a single peduncle bearing a single flower but 'double-flowered' types, where a proportion of the peduncles subtends two flowers, are not uncommon and produce 6–11 % more seed yield than the normal single-flowered type (Sheldrake, Saxena & Krishnamurthy, 1978).

Wilt, incited by *Fusarium oxysporum* f.sp. *ciceri*, is an important cause of crop loss in chickpeas. During the screening of the large chickpea germplasm collection maintained at ICRISAT it became apparent that *kabuli* types (which have white flowers) with wilt resistance are comparatively rare (Kumar & Haware, 1983*a*) and that the combination of double flower with wilt resistance is absent (Kumar & Haware, 1983*b*). It therefore appeared possible that flower colour, the number of flowers per peduncle and wilt resistance are linked.

Resistance in chickpeas to race 1 of *F. oxysporum* f.sp. *ciceri* is known to be controlled by at least three independent loci: two incompletely recessive and one dominant gene individually delay wilting and any two in combination confer complete resistance (Smithson, Kumar & Harjit Singh, 1983). The inheritance of flower colour is controlled by the segregation of two complementary genes and a third gene which supplements one of the others (Ayyar & Balasubramaniam, 1936). The double-flower character is inherited as a monogenic recessive (Athwal & Brar, 1964).

In this report, we describe observations of flower colour and number of flowers per node in populations of crosses made primarily to study the inheritance of wilt resistance and consider their implications with regard to plant improvement.

MATERIALS AND METHODS

The characteristics of the parents used in this study are summarized in Table 1. Crosses of C 104 with WR 315, BG 212 and JG 62 were made in 1978–9 and the cross K 850 × C 104 was made in 1980–1. The F_1s were grown in the field in the off-seasons of 1979 and 1982, the F_2s were grown (also in the field) in 1979–80 and 1982–3. A second F_2 of the cross of C 104 with JG 62 was grown in 1983–4.

The numbers of pink and white-flowered plants were recorded in F_2s of all the crosses. In the F_2 of JG 62 with C 104, the single and double-flowered plants were also counted.

Since individuals susceptible to wilt are usually killed before flowering, the associations between flower characteristics and wilt reaction cannot be examined directly: they can be tested by relating the flower colours and numbers of flowers of F_2 plants grown in the absence of the pathogens to the wilt reactions of their F_3 progenies. The results of these latter tests have already been reported by Kumar & Haware (1982), Upadhyaya *et al.*

Table 1. *Characteristics of parents used in the crosses*

Name	Type	Reaction to wilt	Flower colour	No. of flowers per node
WR 315	*Desi*	Resistant	Pink	1
BG 212	*Desi*	Resistant	Pink	1
K 850	*Desi*	Late-wilting	Pink	1
C 104	*Kabuli*	Late-wilting	White	1
JG 62	*Desi*	Early-wilting	Pink	2

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(1983*a*, *b*) and Harjit Singh *et al.* (1987). χ^2 tests were used to assess goodness of fit to expected ratios and for independent assortment.

RESULTS

All the F_1 plants produced single, pink flowers. In the F_2 populations, the numbers of pink and white-flowered plants were consistent with the segregation of a single locus with pink colour dominant to white (Table 2). The wilt reactions of the F_3 progenies segregated independently of flower colour in the F_2 populations (Table 3).

Table 2. *The numbers of pink and white-flowered plants in* F_2 *populations of four crosses*

Cross	Pink flower	White flower	χ^2 (3:1 ratio)
WR 315 × C 104	145	40	1·13
C 104 × BG 212	184	52	1·11
K 850 × C 104	112	36	0·04
C 104 × JG 62	130	52	1·24
Total	571	180	0·43
Heterogeneity	—	—	3·08

Table 3. *The numbers of early-wilting (EW), late-wilting (LW), segregating and resistant (R)* F_3 *progenies of pink and white-flowered* F_2 *plants of crosses of C* 104 *with WR* 315, *BG* 212 *and K* 850

Wilt reactions of F_3 progenies	Flower colour of F_2 plants: Observed Pink	Observed White	Expected ratio Pink	Expected ratio White	χ^2
	WR 315 × C 104				
All LW	9	2	3	1	
Segregating LW:R (3:1)	11	8	6	2	4·31
All R	5	2	3	1	
Total	25	12	3	1	1·09
	C 104 × BG 212				
All LW	14	1	3	1	
Segregating LW:R (3:1)	23	7	6	2	7·73
All R	15	0	3	1	
Total	52	8	3	1	4·36
	K 850 × C 104				
All EW and LW	33	12	21	7	
Segregating LW:R (3:1)	16	5	12	4	
Segregating EW:LW:R (9:6:1)	21	6	12	4	2·73
All R	2	1	3	1	
Total	72	24	3	1	0

Table 4. *The numbers of early-wilting (EW), late-wilting (LW) and segregating* F_3 *progenies and single and double-flowered and pink and white-flowered plants in* F_2 *populations of the C* 104 *and JG* 62

Wilt reactions of F_2 progenies	No. of flowers per node: Observed Single	Observed Double	Expected ratio Single	Expected ratio Double	χ^2
	Wilt reactions				
All EW	9	2	3	1	
Segregating EW:LW (3:1)	13	9	6	3	6·40
All LW	7	0	3	1	
Total	29	11	3	1	0·13
	Flower colour				
Pink	96	34	9	3	2·38
White	36	16	3	1	
Total	132	50	3	1	0·59

In the F_2 of C 104 × JG 62, the numbers of plants with single (159) and double (53) flowers were consistent with the segregation of a single locus with single-flower dominant to double-flower ($\chi^2 = 0$; $P = 1·0$). The wilt reactions of the F_3 progenies segregated independently of number of flowers in the F_2 generation (Table 4). In the second population of C 104 × JG 62, flower colour and number of flowers also segregated independently (Table 4).

DISCUSSION

Only one of the three loci considered to control flower colour segregated in this study. This locus segregated independently of the locus involved in number of flowers per node and the two controlling wilt reaction.

Thus, the rarity of recombinants between flower colour and wilt reaction appears attributable not to linkage but rather to the low frequencies of the genes in germplasm collections. White-flowered *kabuli* types have cream coloured seeds which are larger and more rounded than the seeds of *desi* types, which are angular and usually brown in colour. *Kabuli* type seeds are preferable to *desi* types in many areas and command a substantial price premium. Following the failure at ICRISAT to identify *kabuli* types with wilt resistance in the germplasm, a breeding program was initiated to incorporate wilt resistance into *kabuli* backgrounds and the characters have now been successfully combined (Kumar & Haware, 1983*a*). Similarly, double-flowered, white-flowered combinations are common.

The locus involved in number of flowers per node segregated independently of the locus delaying wilting in C 104 but the crosses studied provide no evidence regarding linkage between the locus controlling number of flowers and the locus delaying wilting in K 850. Since double-flowered, wilt resistant types were not found in the germplasm collection at ICRISAT, crosses of double-flowered and wilt-resistant lines were made and segregants combining the two characters were isolated (Kumar & Haware, 1983*b*). However, the frequency of double-flowered, wilt-resistant segregants was much less than would be expected from the segregation at two or three loci. This could have occurred because of linkage between the locus controlling number of flowers per node and that delaying wilting in K 850, which suggests the need to use other sources of wilt resistance in breeding to make the combination of desirable characters feasible.

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