

**EVALUATION OF F₃ FAMILIES OF SORGHUM AGAINST EARHEAD
MIDGE, *Contarinia sorghicola* (Coq.) RESISTANCE**

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CERTIFICATE

This is to certify that the thesis entitled "EVALUATION OF F₃ FAMILIES OF SORGHUM AGAINST EARHEAD MIDGE, *Contarinia sorghicola* (Coq.) RESISTANCE" Submitted by Mr. M.H. TATAGAR for the degree of MASTER OF SCIENCE IN AGRICULTURAL ENTOMOLOGY of the University of Agricultural Sciences, Dharwad, is a record of research work done by him during the period of his study in this University under my guidance and supervision, and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

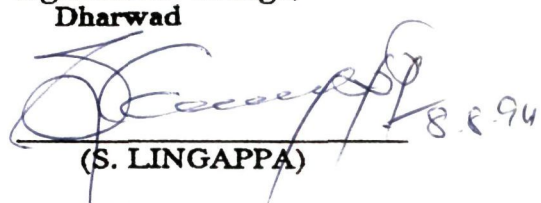
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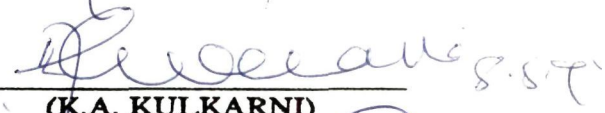
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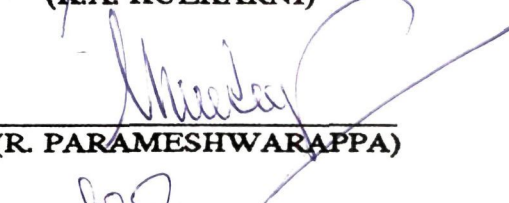

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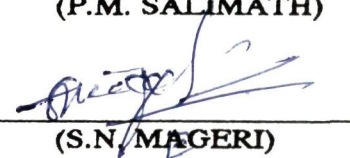
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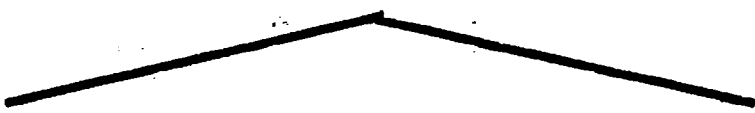
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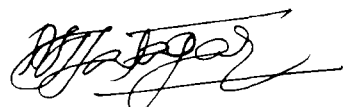
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CONTENTS

CHAPTER	PARTICULARS	PAGE
I	INTRODUCTION	1
II	REVIEW OF LITERATURE	5
	2.1 Nature of damage	5
	2.2 Screening for resistance	5
	2.3 Mechanisms of resistance	11
	2.4 Genetic variability, Heritability and Genetic advance	14
	2.5 Genetic study on midge resistance	15
	2.6 Genetic study on yield traits	17
III	MATERIAL AND METHODS	22
IV	EXPERIMENTAL RESULTS	33
	4.1 Interplant variability among parental strains	33
	4.2 Interplant variability in F_3 generation among three crosses	41
	4.3 Phenotypic variance, genotypic variance, phenotypic coefficient of variability, heritability and genetic advance	49
	4.4 Phenotypic and genotypic correlation among different characters	65
	4.5 Path coefficient analysis	88
V	DISCUSSION	107
VI	SUMMARY	144
VII	REFERENCES	150
	APPENDICES	169

LIST OF TABLES

TABLE	TITLE	PAGE No.
1	Salient features of four sorghum genotypes selected as parents	23
2	Estimates of interplant variability, range, mean, variance, stanard error and coefficent of variability in four parental strains in respect of twelve characters in sorghum	34
3	Estimates of interplant variability, range, mean, variance, stanard error and coefficent of variability in F_3 generation among three crosses in respect of twelve characters	42
4	Estimates of phenotypic and genotypic coefficient of variability, heritability and genetic advance in respect of twelve characters in DJ6514 x SPV829 cross	50
5	Estimates of phenotypic and genotypic coefficient of variability, heritability and genetic advance in respect of twelve characters in TAM2566 x SPV813 cross	55
6	Estimates of phenotypic and genotypic coefficient of variability, heritability and genetic advance in respect of twelve characters in TAM2566 x SPV829 cross	60

TABLE	TITLE	PAGE No.
7	Estimates of phenotypic and genotypic correlation coefficient between different pairs of characters in DJ6514 x SPV829 cross	66
8	Estimates of phenotypic and genotypic correlation coefficient between different pairs of characters in TAM2566 x SPV813 cross	74
9	Estimates of phenotypic and genotypic correlation coefficient between different pairs of characters in TAM2566 x SPV829 cross	82
10	Direct and indirect effects of different characters on grain damage in DJ6514 x SPV829 cross	89
11	Direct and indirect effects of different characters on grain damage in TAM2566 x SPV813 cross	96
12	Direct and indirect effects of different characters on grain damage in TAM2566 x SPV829 cross	102

LIST OF FIGURES

FIGURE	TITLE	BETWEEN PAGES
1	Phenotypic and genotypic coefficients of variability in respect of different characters in DJ6514 x SPV829	119-120
2	Heritability and genetic advance of different characters in DJ6514 x SPV829	121-122
3	Phenotypic and genotypic coefficients of variability in respect of different characters in TAM2566 x SPV813	125-126
4	Heritability and genetic advance of different characters in TAM2566 x SPV813	126-127
5	Phenotypic and genotypic coefficients of variability of different characters TAM2566 x SPV829	128-129
6	Heritability and genetic advance of different characters in TAM2566 x SPV829	129-130
7	Performance of plants in F_3 generation between grain damage and eggs in DJ6514 x SPV829 cross	141-142
8	Performance of plants in F_3 generation between grain damage and larvae in DJ6514 x SPV829 cross	141-142
9	Performance of plants in F_3 generation between grain damage and eggs in TAM2566 x SPV813 cross	141-142

FIGURE	TITLE	BETWEEN PAGES
10	Performance of plants in F ₃ generation between grain damage and larvae in TAM2566 x SPV813 cross	141-142
11	Performance of plants in F ₃ generation between grain damage and eggs in TAM2566 x SPV829 cross	141-142
12	Performance of plants in F ₃ generation between grain damage and larvae in TAM2566 x SPV829 cross	141-142.

CHAPTER - I

INTRODUCTION

I . INTRODUCTION

As a result of introduction of high yielding varieties and hybrids coupled with monocrop the scenario of sorghum (*Sorghum bicolor* (L.) Moench) pest spectrum has changed with the report of as many as 150 insect pests reported on it (Sharma, 1984). Among the major insect pests, the earhead pests alone cause an annual crop loss of more than 972 million rupees (Leushner and Sharma, 1983).

The cecidomyiid midge, a cosmopolitan pest, is responsible for heavy loss of grains in the USA, Argentina, Nigeria, India and Australia. The surveillance studies conducted in Dharwad region (1977-87) indicated the earhead midge, Contarinia sorghicola Coq, as one of the major earhead pests (Hiremath et al., 1988). The extent of crop loss was least, 25 per cent in South Africa on newly introduced varieties (Mathee and Oberholzeer, 1958). Pradhan (1971) opined that due to increase in intensity of cropping of high yielding varieties, the loss due to sorghum midge was as high as 83.7 per cent. Puri (1983) stated that midge incidence on sorghum created nearly famine condition in Vidharbha and Marathwada region of Maharashtra during 1970.

In India, though the incidence of this midge has been reported by Fletcher as early as in 1914, it became a serious pest only after introduction of hybrid sorghum in mid sixties. In Maharashtra and Karnataka, enormous crop loss due to midge has been reported in hybrid sorghum (Karve, 1967 and Kulkarni and Jotwani, 1976). The adult female lays eggs by probing her ovipositor into individual spikelets and the maggot feeds on developing ovary resulting in chaffy spikelets.

Though chemical methods are highly effective they are expensive and difficult to be applied. Secondly due to prolonged infestation, repeated application of insecticide becomes necessary in view of the different maturing genotypes grown in the same area and also because all the farmers do not take up planting simultaneously. Hence development of resistant strains against midge, through plant improvement process would relatively be a long lasting solution for the menace. To start breeding for insect pest resistance, the knowledge of nature of inheritance and existence of variability for resistance is essential to make an effective selection programme. Variability that exists in the midge resistant characters is the sum total of heridity effects of different concerned genes and the effect of environment

(non-heritable). Therefore, it is necessary to partition the variability into heritable and non-heritable components with suitable genetic parameters, such as genotypic and phenotypic coefficients of variability, heritability and genetic advance.

However, inheritance of resistance of one character is often influenced by variation in other characters. Hence knowledge of association between such resistant characters obtainable through estimation of correlation studies helps us to make a better selection.

Correlation coefficients merely describe the extent of association among the resistant characters. It is rather difficult to explain as to how all the influencing characters are related among themselves. Therefore the method of path coefficients analysis is helpful in this regard to partition all the correlation coefficients into direct and indirect effects and in the assessment of relative contribution of selected independent traits to the dependent trait.

Realising the importance and need for such a comprehensive study in sorghum, the present investigation was undertaken with the following objectives.

1. To estimate phenotypic and genotypic variances and covariances for midge resistance.

2. To estimate heritability in broad sense for earhead midge resistance.
3. To estimate genetic advance for earhead midge resistance.
4. To compare phenotypic and genotypic correlation among characters related to midge resistance.
5. To understand the direct and indirect influence of each of different characters in contributing total resistance.

CHAPTER - II

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The earhead midge (*Contarinia sorghicola* Coq.) is the most serious pest of sorghum crop at the earhead stage and has become major constraint in the release of high yielding sorghum types. The resistant types appear to be most needed persuit to combat the problem.

2.1 Nature of damage

The maggot feeds on pollen resulting in failure of fertilization and grain formation (Subramanian Iyer, 1922), fly maggot extracts the juice from the developing seeds in the spikelet thus causing them to shrivel, discolour and dry (Gable *et al.*, 1928; Cowland, 1936; Callan, 1941, Parodi, 1966; Sheshagiri Rao, 1966; Walter, 1941 and Taley, *et al.*, 1971).

Oozing of redcoloured fluid upon squeezing of spikelet is a confirmation of the midge infestation (Montaya, 1965 and Harris, 1970). Danapur (1984) observed that maggot feeding in the middle of the ovary results in the formation of deep grooves. In severe infestation the whole earhead becomes chaffy.

2.2 Screening for resistance

"Resistance is defined as the relative amount of the heritable qualities possessed by plants which influence the ultimate degree of damage caused by insects". (Painter, 1951)

Resistance in sorghum against midge was reported for the first time by Ball and Hastings (1912). The extent of damage by sorghum midge varied with the variety (Cowland, 1936). According to Bowden (1965), the resistance in African "Nunaba" variety was due to long and papery glumes; while Harding (1965) reported a remarkable difference in the number of midges emerging from 12 varieties tested. Rossetto and Benzatto (1967) reported that among 78 varieties screened in Brazil, early flowering varieties were less severely attacked than the late maturing ones. Further they also observed that some late varieties too possessed genetic resistance. According to Parodi and Scantamburlo (1967), dwarf variety from Pretoria, South Africa was found to be resistant. Further, MF2324 a selection named "Grandor" possessed high resistance and high grain yielding ability. Wiseman and McMillion (1968) observed that nine out of 216 lines consistently sustained low damage. Based on the mean number of midges emerged per panicle, 11 lines were selected as promising. According to Johnsen *et al.* (1973), out of the 60 lines, the selection from IS 12612 C, IS 12666 C and IS 2508 C sustained least damage (20%) besides several others that also exhibited significantly less damage. Selection 63/54 and MF 2324 (Wiseman *et al.*, 1974), selection, IS 2663; IS 2660 from

the Indian Rockfeller sorghum collection have also been reported resistant (Berguist *et al.*, 1974).

"HUREIN INTA" a midge resistant variety possessed semicompact panicle with short glumes (Parodi *et al.*, 1974). AF 28, a tall variety with loose head and tight glumes received few midge eggs and was identified as resistant source to sorghum midge (Rossetto *et al.*, 1975).

Shyamsunder *et al.* (1975) indicated DJ-6514, a derivative from shallu x GM 2-3-1, as resistant to midge compared to Swarna and CSH-1. Venugopal *et al.* (1975) reported that entries 92793, 1151, 4870 were highly promising with 5 to 6 per cent grain damage and entries 3472 and 4955 were susceptible with 25 to 29 per cent grain damage. Wiseman *et al.* (1975) screened 200 sorghum lines and assessed the resistance on the basis of 0 to 10 ratings. Parodi *et al.* (1977) produced a male sterile line "1240A INTA" with sorghum midge resistance. The selected resistant line has a fusiform, semicompact panicle and light brown seed with three fourth of the Kernel exposed and one fourth covered by coriaceous glumes having very long whitish hairs.

According to Venugopal *et al.* (1977), DJ 6514 had least per cent grain damage (19.2%) the screening trial

conducted at Coimbatore. Kulkarni *et al.* (1978) opined that DJ 6514 could be a potential parental line in resistance breeding programme. From Brazil Faris *et al.* (1979) reported that AF-28 was the most resistant line based on low adult emergence. Ray Brengman and Peterkeys (1980) identified SC 165 C as a resistant. Some of the resistant types reported from India are TAM 2566, (Jotwani *et al.*, 1981) and DJ 6514 (Natarajan *et al.*, 1981). From 14 sorghum lines evaluated for midge resistance, Mote (1982) observed non blasting entries like IS 1266 and IS 1266 C at milky stage except TAM 2566 (1.72 per cent), DJ 6514 (2.16 per cent) and AF-28 (2.13 per cent) as a resistant.

According to Castille and Quevedo (1981), low incidence of midge occurred on hybrids p-8311 and P-815 compared to hybrids E-591 and D-55 resistance to midge in USA. Out of 400 sorghum lines evaluated by Johnson *et al.* (1981) IS 1309C, 2403C, 2478C, 2508C, 2879C, 2662C, 2757C, 3071C, 644C, 7601C, 7064C, 8100C, 8231C, 8231C, 8233C, 8263C, 833C, 12589C, 12593C, 12609C, 12612C, 12664C, 12666C, 12676C and 12683C were found to possess resistant to midge.

Bhuti and Kulkarni (1982) screened 42 selections from advanced generation material for midge resistance in

Kharif at Dharwad. The damaged heads was lowest in PMR-1060 and PMR-39833 and highest in MRL-Selection -1. Subha Rao *et al.* (1982) reported SPV-354 as resistant source to midge based on rating scale of 0 (no midge) to 10 (over 81 per cent damage). Sharma *et al.* (1983) reported that under no choice conditions more eggs were laid on IS-8544, IS 12664C, CSH-1 and Swarn, while the genotypes AF-28, IS15107 and TAM 2566 had less oviposition and lower larval counts 10 days after midge confinement. The lines S-GIRL-MR-1, TAM-2566, DJ6514 and AF-28 were reported to be quite promising for midge resistance based in the All India Coordinated trials conducted at Delhi, Dharwad, Akola and Parabhani (Anonymous, 1983). Danapur (1984) observed that light yellow colour of anthers attracted more number of midges compared to dark yellow colour and the genotype AF-28 recorded the least grain damage.

Results obtained by Sharma (1984) reveal that sorghum lines AF-28, TAM 2566, DJ 6514, S-Girl-MR-1, IS 12666C were quite promising for the midge resistance and could be used as best potential parents in breeding programme. Hallman *et al.* (1984) studied the relationship of sorghum midge density to damage in resistant and susceptible sorghum hybrids. The resistant hybrid suffered about one fifth as

much damage as the susceptible hybrids because of a reduction in oviposition (45%).

Sharma (1985) recorded 21 sources of resistance from 10,000 germplasms screened at ICRISAT, Hyderabad. ICJV 197, a midge resistant sorghum cultivar was developed from the cross IS 3443 x DJ 6514 using pedigree selection for resistance to midge in the F_2 - F_5 and F_6 bulk evaluations, Sharma *et al.* (1988) included AF-28, S-Girl-MR-1, IS12573C and DJ6514 as highly midge resistant lines based on percentage of chaffy florets. Hagio and Ono (1986) reported that out of 38 varieties tested over 4 years, IS 100 C and IS 2549 2 found to be most resistant. Ramumurthy *et al.* (1990) reported PM 6751, PM 7032, IS 7005, PM 11344, PM 7526, AF 28, DJ6541, PM 7061, PM 7422-2, TAM 2566, PM 7397, PM 7318-2 and IS 19512 as resistant which exhibited lowest incidence (10% damaged panicles).

Besides earlier reviews many workers screened several entries and reported promising entries as follows

Entries	References
1) EC-92792, EC-9274, S-GIRL-MR-1	Raodeo and Karanjkar (1975).
2) I-743, 370, SBH-10, MSH-32, 783, 563 and 654	Chandurwar and Chavan (1976)
3) 36Ax148, 370, 302, R-69, 604, FR-186-1, CSH-5 CK-60B, H-29, CS-3541, R-16, FR-129-1, FR-164-1 and 646x1235	Bapat <i>et al.</i> (1977).
4) SC423 (IS2579C), S-GIRL-MR-1, SC173 (IS2664C)	Jadhav and Jadhav (1978).
5) TAM2566, S-GIRL-MR-`, PM-9026, AF-28, IS-15185, PM-7347, PM-7178, IS-15332, IS-15107, PM-7348 and IS-14775.	Danapur (1984).
6) DJ6514, IS12666C, IS1266C	Natarajan <i>et al.</i> (1981).
7) TAM2566, DJ6514, AF-28, PM-7422-2, PM-11344, IS-19512 and IS-15107	Bhuti and Naik (1989).
8) ICSV197	Agrawal (1987).

2.3 Mechanism of resistance

Non preference for oviposition is an important cause for resistance to midge (Harris, 1961, Wiseman and Mcmillan,

1968). According to Rossetto *et al.* (1975), spikelets closed at the tip apparently make oviposition difficult in AF-28 and hence it was not preferred for oviposition. Similar opinion has also expressed by Sharma (1985), Natarajan and Challaiah (1986) and Singh (1987). Ovipositional nonpreference was the main mechanism in QL38, according to Henzell *et al.* (1989). The other possible resistance mechanism is antibiosis as reported by Gowda and Thontadarya (1975), Rossetto (1977), Page (1979), Melton and Teetes (1984) Sharma *et al.* (1983), Kulkarni (1985), Singh (1987), Segara Caramona *et al.* (1989), Henzell (1989) and Sharma *et al.* (1990).

Some morphological aspects such as closed glume character, compact earhead and cleistogamous flowers, are also associated with midge resistance. According to Ball and Hastings (1912), short glumes were responsible for midge resistance. While Geering (1953) opined that degree of opposition for egg laying in glumes is a factor for resistance. Bowden and Neve (1953) observed that the length and thickness of glumes (Cleistogamous) in Nunaba variety contributed to resistance. Harris (1970) reported that the resistance in this variety was due to the presence of long and papery glumes which interfere in oviposition. Pradhan (1971) and Johnson

et al. (1973) reported resistance in non cleistogamous sorghum also.

In the resistant types like IS 2660 and IS 2663, glumes remained closed throughout the anthesis, While in the susceptible types, B-line 6202 and R-line C 20014 they remained open during anthesis (Berguist *et al.*, 1974).

Rossetto *et al.* (1975) reported that AF-28 was highly resistant to midge attack as it possessed loose head and tight glumes. According to Murthy and Subramaniyam (1978), the resistant line had fusiform and semicompact panicle with light brown seeds three fourth of which was exposed and the rest covered by coriaceous glumes having very long whitish hairs. Further, they also opined that genotypes with compact heads to be resistant and semicompact heads were highly susceptible.

Short and compact glumes in the less susceptible entries remained closed during the anthesis (Jadhav and Jadhav 1978 and Singh, 1987). According to Rossetto (1985), closed glumes being the main cause for nonpreference, this characters existed very much in AF-28 (PI 383856), IS 2660 and IS 2663. Anonymous (1987) developed stable and midge resistant variety,

ICSV197 which possessed semicompact to open panicle with short glumes.

According to Sharma *et al.* (1990) size of floral parts (glume g_1 , glume g_2 , lemma L_1 , lemma L_2) were apparently associated with resistance to midge and reported that sources of resistance are diverse.

2.4 Genetic variability, Heritability and Genetic advance

Galton (1889) for the first time found that part of continuous variation is due to heredity. Johannsen (1909) developed the concept "genotype" and "phenotype". That the phenotype is the resultant interaction of the genotype and environment.

Heritability

The degree to which the variability of quantitative character may be transmitted to the progeny is referred to as heritability. Lush (1940) defined heritability in "broad sense" as the ratio between the genotype as a whole and the phenotype. This would include additive, dominance and epistatic effects of all genes concerned and their interactions with environment.

2.5 Genetic study on midge resistance

Information available on the inheritance of midge resistance is meagre. According to Widstorm *et al.* (1972), when parental, F_2 , F_3 and selfed backcross populations were grown at Tifton and analysed for the genetic means indicated highly significant additive gene effects for both crosses and midge. Dominance effects were significant only for the S-GIRL-MR-1 x 130. Dominance conditions susceptibility to midge injury. Epistatic effects were also present for both crosses and midge and may tend to interfere in selection.

Rossetto and Ogue (1983) made reciprocal crossing between susceptible start and resistant AF-28, but agronomically unacceptable. The damage occurred in the F_1 populations showed that susceptibility is completely or incompletely dominant. Segregation ratios in later generations were consistent with the hypothesis that at least two pairs of recessive major genes determine the resistance in AF-28, but there were indications that genes with minor effects are also present. Some lines derived from F_3 families had good agronomic characteristics and were nearly as resistant as AF-28.

Resistant entries SCO 175, SCO 423, MB-10 and S-GIRL-MR-1 were crossed with susceptible entries wheatland, OK94 and Caprock and studied the genetics of resistance in parents, F_1 , F_2 , F_3 and backcross populations. The midge damage ratings of segregating populations suggested that resistance was controlled by recessive genes at two or more loci. It appears difficult to transfer genes for midge resistance into agronomic B-lines by simple hybridization (Boozy-Angoon *et al.*, 1984).

Agrawal and Abraham (1985) opined that midge resistance is a quantitative inherited trait, controlled by both additive and non-additive, but predominantly by non-additive gene effects. In general midge resistance seems to be genetically simpler than resistance to other insect pests of sorghum.

Agrawal *et al.* (1988) studied the inheritance of resistance to sorghum midge on set of crosses at Dharwad and indicated that both additive and non-additive genetic variances were important for midge resistance. The parents DJ6514 and TAM 2566 proved as better general combiners. Midge resistant parents DJ 6514 and TAM2566, with high *per se* should be utilized in breeding for midge resistance.

Hanna *et al.* (1989) stated that Tift-MR-88, resistant to midge was developed from BC1 population of Redbine 60 x PI 3856, the later parent being the source of resistance. Based on the damage ratings it was indicated that crosses of Tift-MR-88 with susceptible lines are midge susceptible, further opined that its resistance is governed by recessive gene.

2.6 Genetic study on yield traits

2.6.1 Number of days to 50% flowering

Vishwa Swarup and Chaugale (1962a,) observed wide range of phenotypic variability for days to flowering. But genetic coefficient of variation had lower values. Heritability estimate was higher but genetic advance was of lower degree.

High heritability was observed for half blooming in F_3 lines by Liang (1967), Liang and Walter (1967) and Alikhan and Weibel (1969).

Liang *et al.* (1969a) found half bloom characters to be most heritable in F_3 and F_4 generations of two crosses. Sindagi *et al.* (1970b) found flowering date to be least variable and the expected genetic gain was the lowest in both the crosses.

Chung and Liang (1970) observed high heritability values for half bloom date in F_3 and F_4 generations. Similar values were also obtained by Reddy and Liang (1970) in F_1 , F_2 and backcross derivatives of sorghum.

In F_2 and F_3 generations of CK60A x PJ8K, high estimates of heritability and low estimates of genetic advance were observed by Naphade (1973). Flowering date showed comparatively high heritability values (Singh, 1972; Vasudev Rao and Goud, 1977 and Dimmar *et al.*, 1978). However Shinde *et al.* (1979) observed high heritability values with low genetic advance.

Patel *et al.* (1980) recorded low broad sense heritability and low genetic advance to 50% flowering and opined genetic improvement cannot be possible through selection.

High to moderate heritability values were reported for days to 50 per cent flowering by Kukadia *et al.* (1983a), Dinakar (1985) and Shivanna (1989).

2.6.2 Earhead weight

According to Shinde *et al.* (1979), heritability was high and genetic advance was low for earhead weight. Goud *et*

al. (1980) obtained highest phenotypic coefficient, genotypic coefficient of variation and heritability and genetic advance estimates. Similarly high heritability estimates were obtained by Cheralu (1989).

2.6.3 Grain yield per plant

Sindagi et al. (1970b) recorded maximum genetic variation, high heritability and genetic advance in F_2 populations. This indicated that substantial additive gene effects were present and early testing was likely to prove high yielding segregates.

Chung and Liang (1970) obtained moderately high heritability values for grain yield in F_3 and F_4 generations. Similar values were also obtained in F_2 and F_3 generations of CK 60 AX PJ8 K by Naphade (1973).

Gopal Krishna Bhat (1974) recorded the highest phenotypic and genotypic coefficient of variability and moderate heritability in F_2 generations. Artola (1978) and Dimmar and Desai (1978) obtained high broad sense heritability.

In F_1 , F_2 and F_3 generations of forty five crosses high heritability was obtained by Govil et al. (1979). High

heritability values and expected genetic advance were obtained by Patel *et al.* (1980). Phenotypic and genotypic coefficient of variation, heritability estimates and genetic advance were high for grain yield/plant (Kumar and Singh, 1988). High heritability estimates for grain yield was obtained by Cheralu (1989).

2.6.4 Thousand grain weight

Mamdouh *et al.* (1971) obtained low heritability and low expected genetic advance estimates for 100 seed weight; in contrast Singh (1972) obtained high heritability values and high genetic advance for similar character. According to Gopal Krishna Bhat (1974), of the characters observed phenotypic and genotypic coefficients of variation were lowest for 1000 grain weight. Naphade (1973) recorded high heritability values. Similar values were also obtained by Govil *et al.* (1979). Panchal *et al.* (1979), who recorded high values for genotypic coefficient of variation and heritability suggested that it is possible to achieve significant improvement through selection based on phenotypic performance. Patel *et al.* (1980) obtained high estimates of heritability and genetic advance.

Kumar and Singh (1988) obtained high heritability values for 1000 grain weight and indicated that selection for such trait lead to improvement. Where as moderate heritability was obtained by Cheralu and Rao (1989). High genetic variance was recorded and selection for such trait would be useful (Bakheit, 1990).

CHAPTER - III

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The material for the present investigation was obtained from the All India Co-ordinated Sorghum Improvement Project, University of Agricultural Sciences, Dharwad. Prabhu (1989) reported from a diallel study a few F_1 crosses to be outstanding for midge resistance as well as agronomic characters. Further, 25 F_2 crosses were handled by sorghum Entomologists AICSIP, University of Agricultural Sciences, Dharwad. Of these 25 F_2 crosses, best three were selected for the present investigation in F_3 generation. The parentage of material studied in F_3 generation is as below

1. DJ 6514 x SPV 829
2. TAM 2566 x SPV 813
3. TAM 2566 x SPV 829

3.2 Experimental layout

The experiment was laid out in D block which has black soil, during Kharif 1990. The populations of parents and F_3 s were raised in randomised block design over three replications.

The sowing of susceptible popular hybrid CSH-1 was done a fortnight earlier to the sowing of parents and F_3 s so

Table 1. Salient features of parental lines

Sl. No.	Genotype	Pedigree	Days to 50 per cent flowering	Plant height	Thickness	Leaf spreading	Peduncle length	Panicle length	Pigment of plant	Earhead shape	Colour of endosperm	Other remarks	Grain yield kg/ha
1.	DJ6514	A derivative of shallu x CM 2-3-1	70-75	120-180	Slender	Spreading	Short	Long	Light green	Compact elliptic	Light yellow	Highly resistant to midge	1750.00
2.	TAM2566	A derivative of zera zera type	70-75	85-90	Thick	Erect	Long	Short	Purple green	Compact elliptic	Pinkish brown	Highly resistant to midge	2025.00
3.	SPV813	IS3541 x 135	70-75	130-140	Thick	Erect	Short	Long	Green	Semi-loose compact elliptic	Light yellow	Less susceptible to midge	3850.00
4.	SPV829	SPV126 x SPV351	65-70	160-175	Thick	Erect	Short	Long	Light green	Semi-loose Erect primary branches	Light yellow	Less susceptible to midge	3079.00

as to obtain sufficient population of midges for confinement in the cages. The infester rows of CSH-1 were sown on 14th July, 1990 around each plot and also between test rows, alternatively. Each entry was sown in 3m length at a distance of 15cm between plants. The plants were raised following the agronomic and plant production measures till earhead formation as per the recommendations of package of practices (Anonymous, 1987). All the insect pests and diseases infesting upto flowering stage were controlled.

3.3 Artificial infestation of midges

Midge confining cages were used to ensure better infestation level of midges. These cages were made of cylindrical wire frame covered with a fine, blue coloured thin cloth. Since blue colour of thin cloth posses repelling effect inside and ensures maximum oviposition as compared to cages with any other coloured cloth (Sharma, 1985). Those cages were supported by a bamboo stick to cover the whole earhead and provide free space for midge mobility. Caging was done on 20 plants in each parent and on 20 plants in each replication of F_3 from all the three crosses. About 25 field collected female midges were released in each cage for two consequentine days.

3.4 Parameters observed

3.4.1 Days to 50 per cent flowering

The number of days from the date of sowing to the date when approximately 50 per cent of plants were in a bloom were recorded in parents and crosses.

3.4.2 Midge density

The average number of adult midges per panicle were counted by trapping adult flies in a polythene bag at the time of peak activity between 8-30 a.m to 10-30 a.m. on the day of 90 per cent ear head emergence.

3.4.3 Anther colour

Based on visual observation anther colour was graded as follows.

1 = Light yellow.

2 = Medium yellow.

3 = Yellow

4 = Deep yellow.

3.4.4 Eggs per hundred florets

Hundred spikelets were removed randomly from each earhead on 20 plants in each parent and on 20 plants in each replication of each cross 2 days after caging and eggs were counted under stereoscopic microscope.

3.4.5 Larvae per hundred florets

Hundred spikelets from different parts of each earhead were removed on ninth day after caging and each spikelet was crushed between two fingers. The red liquid ooze indicated the presence of larvae.

3.4.6 Glume length

The outer (G_1) and the inner (G_2) glumes were dissected and measured with the help of ocular micrometer. Three florets were taken from each earhead.

3.4.7 Per cent grain damage

Hundred spikelets sampling from top, middle and bottom portions were removed from each earhead. The number of chaffy spikelets were counted and percentage damage was workedout.

3.4.8 Adult emergence

The number of adults emerged from each caged earhead were counted after 30 days from caging when midge emergence was completed.

3.4.9 Earhead weight per plant (g)

The earheads were weighed separately after harvest.

3.4.10 Grain yield per plant (g)

The grain yield per plant was recorded after threshing.

3.4.11 Hundred grain weight (g)

Samples of 100 grain from each earhead were taken out and weight was recorded separately.

3.5 Statistical procedures

Data on plant basis were used for the purpose. Each parent and cross formed a separate population.

To workout interplant variability in each parent and cross the following statistical procedures were followed.

$$1. \text{ Mean} = \frac{\sum x}{n}$$

Where $\sum x$ = Sum of all the 'n' observations.

n = number of observations

$$2. \text{ Variance} = \frac{SS - CF}{D.F}$$

S.S = Sum of squares of all the observations
of a variate

$$C.F = \frac{(\text{Grand total})^2}{n} = \frac{(\sum x)^2}{n}$$

D.F = Degree of freedom.

$$(iii) \text{ Standard Error} = \sqrt{\frac{\text{Variance}}{n}}$$

n = number of observations.

(iv) Coefficient of variability = $\frac{\sigma^-}{\text{Mean}} \times 100$

Where σ^- = Standard deviation.

(v) Range = Vlues between the lowest and highest.

Variation in non segregating generations i.e., parental generations was taken as Environmental variation (EV) while variation of the F_3 was taken as phenotypic variance (V_p). The phenotypic and environmental variance were then computed for each cross as follows.

$$V_E = \frac{V_{p_1} + V_{p_2}}{2}$$

Phenotypic variance (V_p) = Variation of F_3 generation (V_{F_3})

Where P_1 and P_2 are the parents of the F_3 cross.

Genotypic Variance (G_v) then computed as follows.

$$V_g = V_p - V_E$$

Likewise phenotypic covariance and genotypic covariance were calculated.

3.5.1 Phenotypic and Genotypic coefficient of variability

The formulae outlined by Burton (1952) were used for calculating these parameters.

Phenotypic coefficient of variability (PCV)

$$= \frac{\sigma_p}{\bar{X}} \times 100$$

Genotypic coefficient of variability (GCV)

$$\frac{\sigma_g}{\bar{X}} \times 100$$

where, σ_P = Phenotypic standard deviation.

σ_g = Genotypic standard deviation.

$\bar{X}$ = Mean of the character.

3.5.2 Heritability

Heritability (H or % h^2) in broad sense was calculated by using the formula given below (Lush, 1940).

$$h^2 (\%) = \frac{\sigma_g^2}{\sigma_P^2} \times 100$$

where, σ_g^2 = Genotypic variance.

σ_P^2 = Phenotypic variance.

3.5.3 Genetic advance

The extent of genetic gain which could be expected through selection can be predicted according to the formula suggested by Lush (1940).

$$\text{Genetic advance} = \sigma_P h^2 K$$

where, σ_P^2 = Standard deviation of the phenotypic variance.

h^2 = Heritability in brood sense.

K = Selection intensity (at 5% = 2.06)

3.5.4 Genetic advance as per cent of mean (GAM)

Genetic advance over mean expressed as per cent of mean.

$$GAM = \frac{GA}{\bar{X}} \times 100$$

3.5.5 Correlation coefficients

Correlation coefficient were calculated by the formula suggested by Robinson et al. (1951). Variance and covariance components workedout were utilized in the following formula to calculate phenotypic correlations.

3.5.6 Phenotypic correlation coefficients

$$r_{ph} = \frac{\sigma_{ph} 1.2}{\sqrt{(\sigma_{ph} 1)^2 \times (\sigma_{ph} 2)^2}}$$

Where r_{ph} = Phenotypic correlation coefficient

$\sigma_{ph} 1.2$ = Phenotypic covariance between two traits (1 and 2)

$\sigma_{ph} 1^2$ = Phenotypic variance of the first trait.

$\sigma_{ph} 2^2$ = Phenotypic variance of the second trait.

3.5.7 Genotypic correlation coefficients (r_g)

Genotypic covariance was obtained by deducting error covariance from phenotypic covariance. Then genotypic correlation coefficient was obtained by the following formula:

$$r_g = \frac{\sigma_g 1.2}{\sqrt{(\sigma_g 1)^2 \times (\sigma_g 2)^2}}$$

Where,

$\sigma_{g.2}$ = genotypic covariance between two traits (1 and 2)

$\sigma_{g_1}^2$ = Genotypic variance of the first trait.

$\sigma_{g_2}^2$ = Genotypic variance of the second trait.

3.5.8 Path coefficient analysis

Path coefficient analysis was carried out using the phenotypic correlation coefficient to know the direct and indirect effects of different traits on dependent trait (Percentage of grain damage) as suggested by Wright (1921) and illustrated by Dewey and Lu (1957).

Standard path coefficients which are the standard partial regression coefficients were obtained by solving the following set of 'P' simultaneous equations through the use of "Doolite Technique" as described by Goulden (1959).

$$P_{01} + P_{02}r_{12} + \dots + P_{op}r_{1p} = r_{01}$$

$$P_{01} + P_{02} + \dots + P_{op}r_{2p} = r_{02}$$

$$P_{op}r_{1p} + P_{02}r_{2p} + \dots + P_{0p} = r_{op}$$

Where,

$P_{01}, P_{02} \dots P_{0p}$ are the direct path coefficient of variable $s_1, s_2 \dots P$ on the dependent variable 0 . $r_{12}, r_{13} \dots r_{1p} \dots r_p(p-1)$ are the possible correlation coefficients between various independent variables and $r_{01},$

$r_{02} \dots \dots \dots r_{0p}$ are the correlations between dependent variables and independent variables.

The indirect effect of the i^{th} variable via the j^{th} variable is obtained as $(P_{oj} \times r_{ij})$. The contribution of the remaining unknown factors is measured as the residual factor which is calculated as given below.

$$P_0^2 \times = 1 - (P_{01}^2 + 2P_{01} P_{02} r_{12} + 2P_{01} P_{03} r_{13} + P_{02}^2 + 2P_{02} P_{03} r_{13} + P_{0p}^2)$$

$$\text{Residual factor} = \sqrt{P_{ox}^2}$$

CHAPTER - IV

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

4.1 Interplant variability among parental strains

The details of interplant variability such as range, mean, variance and coefficient of variability in respect of different characters are in four parental lines used in the study are presented in table-2.

4.1.1 Days to 50 per cent flowering

From the table, it is clear that among parents DJ6514 and TAM2566 exhibited similar range (73-75) followed by SPV813 (70-73) and SPV829 (64-69). The earliest to flower was SPV829 as indicated by its mean 66.50 days. The highest mean value of 74.10 days was recorded in both DJ6514 and TAM2566. SPV813 showed the mean of 71.20 days. The lowest variance of 0.59 was noticed in DJ 6514 and TAM2566 and the highest of 1.45 in SPV829. Parent SPV813 showed the variance of 1.06. The coefficient of variability for this character ranged from 1.04 (TAM2566) to 1.81 (SPV829) and the values of 1.26 and 1.45 were exhibited by DJ6514 and SPV813, respectively.

4.1.2 Anther colour

Of the four parents, a range of 2-3 was manifested by DJ6514 and SPV813. In the case of SPV829, the range was

Table 2. Estimates of interplant variability, range, mean, variance, standard error and coefficient of variability in parental strains

Genotypes	Range	Mean	Variance	Standard error	C.V. (%)
1. Days to 50% flowering					
DJ6514	73 - 75	74.10	0.59	±0.17	1.26
SPV829	64 - 69	66.50	1.45	±0.27	1.81
TAM2566	73 - 75	74.10	0.59	±0.17	1.04
SPV813	70 - 73	71.20	1.06	±0.23	1.45
2. Anther colour					
DJ6514	2 - 3	2.20	0.16	±0.09	18.18
SPV829	2 - 4	3.25	0.39	±0.14	19.15
TAM2566	3 - 4	3.80	0.16	±0.09	10.53
SPV813	2 - 3	2.60	0.24	±0.11	18.84
3. Number of adult midges/earhead					
DJ6514	3 - 9	6.55	2.85	±0.38	25.76
SPV829	3 - 11	7.20	5.86	±0.54	33.62
TAM2566	3 - 8	6.15	2.53	±0.36	25.85
SPV813	4 - 11	7.00	3.30	±0.41	25.95
4. Glume length-G1 (mm)					
DJ6514	2.80 - 3.10	3.06	0.003	±0.012	1.78
SPV829	3.29 - 3.68	3.41	0.002	±0.010	1.31
TAM2566	2.93 - 3.18	2.96	0.006	±0.019	2.79
SPV813	3.00 - 3.28	3.05	0.004	±0.014	2.12
5. Glume length-G2 (mm)					
DJ6514	2.87 - 3.14	3.04	0.004	±0.014	2.08
SPV829	4.03 - 4.10	4.07	0.003	±0.011	1.50
TAM2566	3.08 - 3.17	3.14	0.005	±0.016	2.24
SPV813	3.55 - 4.56	4.12	0.006	±0.017	1.88
6. Eggs per 100 florets					
DJ6514	21 - 36	28.90	12.89	±0.80	12.42
SPV829	21 - 45	33.15	34.63	±1.32	17.75
TAM2566	6 - 18	12.25	15.09	±0.87	31.71
SPV813	15 - 45	27.60	53.24	±1.63	26.44

Table 2. (Contd...)

Genotypes	Range	Mean	Variance	Standard error	C.V. (%)
7. Larvae per 100 florets					
DJ6514	6 - 11	8.15	2.43	±0.35	19.12
SPV829	25 - 47	36.80	27.06	±1.16	14.14
TAM2566	8 - 18	13.00	9.00	±0.67	23.08
SPV813	24 - 43	32.70	21.01	±1.02	14.02
8. Per cent grain damage (Chaffiness)					
DJ6514	11.54 - 19.37	14.73	3.38	±0.41	12.48
SPV829	24.35 - 33.83	29.14	5.41	±0.52	7.98
TAM2566	12.92 - 25.84	18.58	10.66	±0.73	17.57
SPV813	21.97 - 31.31	27.69	7.00	±0.59	9.55
9. Adult emergence per earhead					
DJ6514	7.00 - 31.00	14.75	27.14	±1.16	33.88
SPV829	24.00 - 51.00	34.05	51.94	±1.61	21.17
TAM2566	9.00 - 31.00	19.60	34.25	±1.31	29.86
SPV813	21.00 - 52.00	39.85	57.29	±1.69	18.99
10. Earhead weight/plant (g)					
DJ6514	45.50 - 65.50	55.48	18.17	±0.95	7.68
SPV829	35.50 - 48.50	42.00	11.78	±0.77	8.17
TAM2566	76.50 - 95.50	89.17	21.17	±1.03	5.16
SPV813	27.50 - 49.80	36.69	26.53	±1.15	14.04
11. Grain yield/plant (g)					
DJ6514	24.75 - 45.25	29.63	5.26	±0.51	7.74
SPV829	20.50 - 32.60	27.58	8.46	±0.65	10.54
TAM2566	35.00 - 67.00	49.60	4.21	±0.29	4.13
SPV813	18.00 - 24.80	20.14	2.54	±0.36	7.91
12. 100 grain weight (g)					
DJ6514	1.58 - 1.98	1.88	0.010	±0.02	4.67
SPV829	1.84 - 2.14	1.99	0.001	±0.007	1.50
TAM2566	2.50 - 3.09	2.65	0.005	±0.043	2.66
SPV813	1.80 - 2.18	1.85	0.007	±0.063	4.52

2-4, while it was 3-4 for the parent TAM2566. The highest mean of 3.80 was noticed in TAM2566 and the lowest in DJ 6514 (2.20). The mean values of 2.60 and 3.25 were shown by SPV813 and SPV829, respectively. Variance of 0.16 was noticed in parents DJ6514 and TAM2566. Parents SPV813 and SPV829 exhibited variance of 0.24 and 0.39, respectively. The least coefficient of variability observed was 10.53 (TAM 2566) and the highest was 19.15 (SPV829) for this character. The other two parents showed coefficient of variability values of 18.18 (DJ6514) and 18.84 (SPV813).

4.1.3 Number of adult midges/ear head

The lowest range for this trait was found in TAM2566 (3-8) followed by DJ6514 (3-9), 3-11 (SPV-829) and 4-11 (SPV813). The mean values were 6.15, 6.55, 7.00 and 7.20 noticed in TAM2566, DJ6514, SPV813 and SPV829, respectively. The least variance (2.53) observed was in TAM2566 as compared to highest (5.86) in SPV829. DJ6514 and SPV813 showed variance estimates of 2.85 and 3.30, respectively. Although SPV829 exhibited high coefficient of variability of 33.62, the other parents also exhibited more or less similar variability.

4.1.4 Glume length - G_1 (mm)

It could be seen from the table that the parental strains exhibited range the values of which were found to be the glume length ranged from 3.07-3.18 mm (TAM2566), 3.24-3.30mm (DJ6514), 3.35-3.50 (SPV 813) and 4.0 to 4.04 mm (SPV829). The lowest mean of 2.96 mm was recorded by TAM2566 and the highest of 3.41 mm was noticed in SPV829. The other two parents recorded closer mean values of 3.05 mm (SPV813) and 3.06mm (DJ6514). The coefficient of variability ranged from 1.13 to 2.79. SPV829 exhibited the least variability and TAM2566 the highest. The values for other two parents were 1.78 for (DJ6514) and 2.12 for (SPV813).

4.1.5 Glume length - G_2 (mm)

As indicated by the table, the range was highest (3.55-6.67mm) with a mean value of 4.12mm in SPV813 and lowest range (3.08-3.17mm) and mean (3.14mm) in TAM2566. The glume length (G_2) in SPV829 the ranged from 4.03-4.10mm and with a mean values of 4.07mm. DJ6514 recorded the range of 3.22-3.27mm and mean of 3.25mm. The coefficient of variability (2.24%) was highest in TAM2566 and lowest (1.50%) in SPV829, accordingly variances were 0.005 and 0.005. The CV of DJ6514 was 2.08 per cent followed by SPV813 (1.88%).

4.1.6 Eggs per hundred florets

Among the parental lines, the variation in number of eggs per hundred florets was least in TAM2566 (6-18) and highest (21-45) in SPV829 followed by DJ6514 (15-45). Mean number of eggs (12.25) was lowest in TAM2566 and highest (33.15) in SPV829. The mean values for other two parents were 27.6 (SPV813) and 28.9 (DJ6514). The parent DJ 6514 showed least variance and coefficient of variability (12.42). Although TAM2566 showed moderate variance of 15.09, it exhibited high coefficient of variability of 31.71 per cent. The highest variance was noticed in SPV813 (53.24) and its variability was 26.44 per cent.

4.1.7 Larvae per hundred florets

Among the parents, the lowest range (6-11) and mean (8.15) for this trait were manifested by DJ6514, while the highest range (25-47) and the mean (36.80) were recorded by SPV829. Other two parents recorded of 8-18 (TAM2566) and 24-43 (SPV813) larvae with the corresponding mean values of 13.00 and 32.70, respectively. The least variance was noticed in DJ6514 (2.43) and the highest in SPV829 (27.06). SPV813 exhibited the least coefficient of variability (14.02%) while the highest coefficient variability was shown by TAM2566 (23.08%). The other two parents showed coefficient of

variability estimates of 14.14 (SPV829) and 19.12 (DJ6514) per cent.

4.1.8 Grain damage (chaffiness)

It could be seen from the table that among parents the least (14.73) per cent grain damage was exhibited by DJ6514 as with a narrow range of (11.54 - 19.37). The highest mean (29.14) with a wider range (24.34 - 33.83) was noticed in SPV829 followed by SPV813 and TAM2566.

Highest coefficient of variability among parents was recorded in TAM2566 (17.57%) with a highest variance of 10.66. SPV 829 showed the least coefficient of variability (7.98%) and the variance was 5.14. While the variance was lowest in DJ6514, the variability was (12.48%).

4.1.9 Adult emergence per earhead

The range of 7-31 eggs in DJ6514 was averaged to 14.75 as compared to 9-31 with a mean value of 19.6 in TAM2566. SPV813 recorded the highest mean (39.85) followed by SPV829 (34.05).

Least coefficient of variability (18.99%) was exhibited by SPV813 with variance of 57.29 followed by SPV829 (21.17) with a variance of 51.94. The coefficient of

variability values were high for DJ6514 (33.88) and TAM2566 (29.86).

4.1.10 Earhead weight per plant (g)

As revealed in the table, the highest range (76.50 - 95.50) and mean (89.17) were exhibited by TAM2566 followed by DJ6514 which showed a range of 45.50 - 65.50 and mean of 55.48. The ranges for other two parents SPV 829 and SPV813 were 35.50 - 48.50 and 27.50 - 49.50 and means values were 42.00 and 36.69, respectively. The highest variance (26-53) and coefficient of variability (14.04%) was noticed in SPV813 while variability of 8.17, 7.68, 5.16 and variance of 11.78, 18.17 and 21.17 were in parents SPV829, DJ6514 and TAM2566, respectively.

4.1.11 Grain yield per plant (g)

While the per plant yield ranged from 45-67g in TAM2566, it averaged to 49.6 followed by DJ6514 (range, 24.75 - 45.25g and mean, 29.65). SPV813 exhibited the minimum range (18.00-24.80) its mean was 20.14. The range noticed for SPV829 was 20.50 - 32.60g and mean was 27.58g. The highest coefficient of variability (10.54%) and variance (8.46) was expressed by SPV829 and the least CV (7.74) by DJ6514.

4.1.12 Hundred grain weight (g)

The highest range (2.50-3.09g) and mean (2.65g) for this trait was noticed in TAM2566 and in contrast to narrow range of DJ6514 (1.58 -1.98) and the mean of 1.88 in SPV813. It was SPV829 which showed lowest coefficient of variability 1.50 per cent with a variance of 0.001 while DJ6514 recorded the highest CV (4.67%) with its variance of 0.01 followed by SPV813.

4.2 Interplant variability in F_3 generation

Interplant variability in F_3 families of all three crosses in respect of different characters is presented in Table 3.

4.2.1 Days to 50 per cent flowering

Ranges for days to 50 per cent flowering in three crosses viz., TAM2566 x SPV829 (63-78 days), DJ6514 x SPV 829 (63-79 days) and TAM2566 x SPV813 (65-79 days) were more or less similar and the means were 70.00 71.43 and 71.13 days, respectively. Highest coefficient of variability was found in TAM 2566 x SPV829 (5.64) with a variance of 15.60 followed by DJ6514 x SPV829 (5.59% CV) and (15.95) variance. TAM2566 x SPV813 showed CV of 5.13 per cent and the variance of 14.25.

Table 3. Estimates of interplant variability, range, mean, variance⁴², standard error and coefficient of variability in F₃ generation among three crosses

Crosses	Range	Mean	Variance	Standard error	C.V. (%)
1. Days to 50% flowering					
DJ6514 x SPV829	63 - 79	71.43	15.95	±0.52	5.59
TAM2566 x SPV813	65 - 79	71.13	14.25	±0.49	5.31
TAM2566 x SPV829	63 - 78	70.00	15.60	±0.51	5.64
2. Anther colour					
DJ6514 x SPV829	1 - 4	2.35	1.09	±0.14	44.51
TAM2566 x SPV813	1 - 4	3.02	0.65	±0.10	26.72
TAM2566 x SPV829	2 - 4	3.63	1.68	±0.29	35.70
3. Number of adult midges/earhead					
DJ6514 x SPV829	3 - 16	8.15	8.23	±0.37	35.19
TAM2566 x SPV813	3 - 19	6.80	10.86	±0.43	48.46
TAM2566 x SPV829	2 - 25	8.85	21.13	±0.59	51.94
4. Glume length-G1 (mm)					
DJ6514 x SPV829	2.95 - 3.78	3.44	0.020	±0.020	4.33
TAM2566 x SPV813	2.03 - 3.50	2.99	0.040	±0.030	7.04
TAM2566 x SPV829	2.67 - 3.62	3.34	0.050	±0.030	6.68
5. Glume length-G2 (mm)					
DJ6514 x SPV829	3.05 - 3.68	3.44	0.02	±0.02	3.59
TAM2566 x SPV813	2.74 - 3.64	3.04	0.03	±0.02	6.12
TAM2566 x SPV829	2.63 - 3.60	3.32	0.05	±0.03	6.65
6. Eggs per 100 florets					
DJ6514 x SPV829	7 - 69	34.20	138.19	±1.52	34.37
TAM2566 x SPV813	7 - 99	33.45	277.31	±2.15	49.78
TAM2566 x SPV829	5 - 79	27.16	212.46	±1.88	53.67

Table 3. (Contd...)

Crosses	Range	Mean	Variance	Standard error	C.V. (%)
7. Larvae per 100 florets					
DJ6514 x SPV829	6 - 61	29.05	109.64	±1.35	36.04
TAM2566 x SPV813	2 - 64	24.15	126.83	±1.45	46.63
TAM2566 x SPV829	3 - 64	27.60	172.41	±1.70	47.57
8. Per cent grain damage (Chaffiness)					
DJ6514xSPV829	12.92 - 43.28	28.95	42.24	±0.84	22.83
TAM2566xSPV813	9.98 - 50.18	27.17	42.45	±0.84	23.98
TAM2566xSPV829	12.92 - 46.72	28.67	42.04	±0.84	22.03
9. Adult emergence per earhead					
DJ6514xSPV829	11.00 - 53.00	32.03	88.00	±1.21	29.28
TAM2566xSPV813	15.00 - 57.00	30.67	106.39	±1.33	33.63
TAM2566xSPV829	15.00 - 62.00	34.55	167.05	±1.67	37.41
10. Earhead weight/plant (g)					
DJ6514xSPV829	15.50 - 45.20	26.69	35.21	±0.76	22.23
TAM2566xSPV813	15 - 68	28.58	91.15	±1.23	33.40
TAM2566xSPV829	28 - 79.20	45.66	150.30	±1.58	26.85
11. Grain yield/plant (g)					
DJ6514xSPV829	9.00 - 32.20	18.55	31.63	±1.25	30.31
TAM2566xSPV813	7.50 - 53.00	23.52	42.10	±1.45	27.91
TAM2566xSPV829	10.75 - 68.50	31.40	143.61	±1.55	38.16
12. 100 grain weight (g)					
DJ6514xSPV829	1.35 - 2.55	1.78	0.040	±0.040	11.23
TAM2566xSPV813	1.60 - 2.77	2.09	0.060	±0.030	11.46
TAM2566xSPV829	2.01 - 3.02	2.50	0.050	±0.030	9.33

4.2.2 Anther colour

Among the three crosses, TAM2566 x SPV829 exhibited highest grade as indicated by its mean of 3.63 and range was 2-4. While lowest grade (2.35) was manifested by DJ 6514 x SPV829, with the range of 1-4. TAM2566 x SPV813 showed the range of 1-4 and mean of 3.02. The least coefficient of variability (26.72%) and the highest (44.51%) were recorded in TAM2566 x SPV813 and DJ6514 x SPV829, respectively, with the variances of 6.09 and 1.09, respectively. TAM2566 x SPV829 recorded 1.68 variance while the variability was 35.70 per cent.

4.2.3 Number of adult midges per earhead

It could be seen from the table 3, that the least number of midges per earhead was recorded in TAM2566 x SPV813 (6.80) with a range of 3-19. The highest number of midges (8.85) with a range of 2-25 was noticed in TAM2566 x SPV829. DJ6514 x SPV829 showed a range of 3-16 and mean of 8.15. The highest CV (51.94%) and variance (21.13) were exhibited by TAM2566 x SPV829 followed by TAM2566 x SPV813 (48.46%) CV and 10.83 variance. Coefficient of variability for the other cross DJ6514 x TAM2566 was 35.19 per cent and variance estimate was 8.23.

4.2.4 Glume length - G_1 (mm)

It is evident from the table that among the three crosses, the highest range (2.95 - 3.78 mm) and mean (3.44mm) were exhibited by DJ6514 x TAM2566, while the lowest mean (2.19mm) and range (2.03 - 3.50mm) were observed in the cross TAM2566 x SPV813. Range in the case of TAM2566 x SPV829 was (2.67-3.62mm) and its mean was 3.34 mm. The least coefficient of variability (4.33%) and least variance (0.02) were recorded in DJ6514 x SPV829, while the highest CV (7.04%) was noticed in TAM2566 x SPV813 with a variance estimate of 0.04. Variance estimate in the case of TAM2566 x SPV829 was 0.05 while its CV was 6.68 per cent.

4.2.5 Glume length - G_2 (mm)

The highest mean (3.44mm) for this trait was expressed by DJ 6514 x SPV829. While TAM2566 x SPV829 exhibited least mean of 3.32 mm with its range of 2.63-3.60mm, the values were slightly high for TAM2566 x SPV813. The highest coefficient of variability (6.65%) was noticed in TAM2566 x SPV829 with a variance value of 0.05. TAM 2566 x SPV813 showed CV estimate of 6.12 per cent and variance estimate of 0.03. The cross DJ6514 x SPV829 exhibited least coefficient of variability (3.59%) and variance (0.02).

4.2.6 Number of eggs per hundred florets

From the table it is clear that the least number of eggs per hundred florets (27.16) was recorded in TAM2566 x SPV829 with a range of 5-79 eggs. The highest mean number of eggs recorded (34.20) was in DJ6514 x SPV829 with a range of 7-69 eggs per hundred florets. Although wider range for this character was exhibited by TAM2566 x SPV813 (7-99), moderate mean of 33.45 eggs was noticed. The least coefficient of variability (34.37%) and the highest CV (53.67%) were observed in DJ6514 x SPV829 and TAM2566 x SPV829, respectively. The variances were 1.52 and 1.88, respectively. TAM2566 x SPV 813 showed variance of 2.15 and CV was 49.78 per cent.

4.2.7 Larvae per hundred florets

Among crosses, TAM2566 x SPV813 Showed the least mean number of larvae (24.15) per hundred florets with a wider range of 2-64, followed by TAM2566 x SPV829 which exhibited the mean of 27.60 larvae and the range 3-64 larvae per hundred florets. The highest number of larvae were found in DJ6514 x SPV829 (29.05) and its range was 6-61 larvae. Least variance (109.64) and CV (36.04%) were recorded in DJ6514 x SPV829, while highest variance (172.41) and CV (47.57%) were exhibited by TAM2566 x SPV829. TAM2566 x SPV 813 had a CV of 46.63 and its variance was 126.83.

4.2.8 Per cent grain damage (chaffiness)

Among the three crosses least mean per cent grain damage (27.17) was exhibited by TAM2566 x SPV813, while other crosses TAM2566 x SPV829 and DJ6514 x SPV829 showed mean of 28.67 and 28.95, respectively. Ranges were 9.98 - 50.18 (TAM2566 x SPV813), 12.98 - 46.72 (TAM2566 x SPV829) and 12.92 - 43.28 (DJ6514 x SPV829).

Highest coefficient of variability of 23.98 per cent was noticed in TAM2566 x SPV813 and with the variance of 42.45. The corresponding values for DJ6514 x SPV829 were 22.83 per cent and 29.66. Least CV 23.03 per cent was for TAM2566 x SPV829 with a variance of 42.84.

4.2.9 Adult emergence per earhead

Least mean number of adult emergence (30.67) was noticed in TAM2566 x SPV813 followed by DJ6514 x SPV829. TAM2566 x SPV829 recorded highest mean (34.55) and the range (15-62).

TAM2566 x SPV829 recorded the highest coefficient of variability (37.41%) and its variance was 167.05 as against the least CV of 29.28 per cent and variance of 88.00 in DJ6514 x SPV829.

4.2.10 Earhead weight per plant (g)

From the table it could be seen that highest earhead weight per plant (45.66) was recorded in TAM2566 x SPV829 which had a wider range (28-79.20). DJ6514 x SPV829 recorded the lowest earhead weight per plant (26.6) with a range of 15.50- 45.20g. Cross between TAM2566 x SPV813 stretched its range from 15 to 68g and with mean of 28.58g. The highest coefficient of variability (33.40%) was exhibited by TAM2566 x SPV813 and variance was 91.15. TAM2566 x SPV829 recorded the highest variance (150.30) while its CV was 26.85 per cent. The least CV (22.23) was noticed in DJ6514 x SPV829 with a variance of 35.21.

4.2.11 Grain yield per plant (g)

DJ6514 x SPV829 showed lowest mean grain yield (18.55 g) per plant among 3 crosses, with a narrow range of 9-32.20g. On the contrary, TAM2566 x SPV829 exhibited the highest range (10.75 - 68.50 g) and mean (31.40 g). The corresponding values for TAM2566 x SPV813 were 7.50 - 53.00 g and 23.51g. The highest variance (143.61) and CV (38.76%) were recorded in TAM2566 x SPV829 but lowest estimate of variance (31.63) was exhibited by DJ6514 x SPV829 and its CV was 30.31. TAM2566 x SPV813 showed the least coefficient of variability (27.91%) which had a variance estimate of 42.10.

4.2.12 Hundred grain weight (g)

A range of 2.01 - 3.02 g was noticed in TAM2566 x SPV829 mean of 2.50 g among three crosses. In contrast to this, lowest mean (1.78g) and range (1.35 -2.55g) was recorded in DJ6514 x SPV829. A mean of 2.09g was observed in the case of TAM2566 x SPV813 with a range of 1.60 - 2.77g. The least coefficient of variability (9.33%) was observed in TAM2566 x SPV829 with a variance of 0.05. TAM2566 x SPV829 and DJ 6514 x SPV829, exhibited the CV values of 11.46 and 11.23 per cent and their variances were 0.06 and 0.04, respectively.

4.3 DJ6514 x SPV829

Genetic parameters such as phenotypic variance (PV), genotypic variance (GV), phenotypic coefficient of variability (PCV), genotypic coefficient of variability (GCV), heritability and genetic advance in respect of different characters for the cross DJ6514 x SPV829 in F_3 generation are presented in Table 4, Fig. 1 and 2.

4.3.1 Days to 50 per cent flowering

The cross exhibited less phenotypic (15.95) and genotypic (15.67) variance. Phenotypic coefficient of variability was 5.95 and GCV was 5.54.

Among all characters studied, this trait showed high heritability of 98.28 percentage with a genetic advance of 8.08.

4.3.2 Anther colour

Genotypic variance for anther colour was 0.82 and PV was (1.09). The phenotypic coefficient of variability was 44.51 as against the genotypic coefficient of variability of 38.53. This trait showed high heritability (75.22), however genetic advance was (1.60)

4.3.3 Number of adult midges per earhead

The cross exhibited phenotypic variance of 8.23 and genotypic variance of 3.87 for this character. The PCV and GCV were 35.19 per cent and 24.15 per cent, respectively. Genetic advance of 2.78 with a moderate heritability of 47.07 per cent was noticed for this character.

4.3.4 Glume length - G_1

The genotypic variance for this character was 0.01 as against the phenotypic variance of 0.02. Phenotypic coefficient of variability was 4.33 per cent and GCV was 3.99 per cent.

Glume length exhibited high heritability (90.00 per cent) and genetic advance was only 0.26.

4.3.5 Glume length - G_2

The phenotypic variance was 0.02 and genotypic variance was 0.017. The percentage of phenotypic coefficient of variability was 4.33 and GCV was 3.79.

Estimate of Genetic advance was 0.24 and that of heritability was 85.00 per cent.

4.3.6 Number of eggs per hundred florets

Genotypic variance for this character was 114.43 and phenotypic variance was 138.76. The phenotypic coefficient of variability was 34.37 per cent as against the GCV of 31.28.

Heritability was 82.81 per cent with genetic advance of 20.05.

4.3.7 Number of larvae per hundred florets

As indicated in the table, high phenotypic (109.64) and genotypic variance (94.90) were noticed for this character. The genotypic coefficient of variability was 33.53, while phenotypic coefficient of variability was 36.04.

Although genetic advance (18.67) was moderately low, the heritability of 86.55 per cent was found to be high.

4.3.8 Per cent grain damage (chaffiness)

Phenotypic and genotypic variances were 29.66 and 19.95, respectively. The per cent phenotypic coefficient of

variability was 18.81, while genotypic coefficient variability was 15.43.

Highest heritability of 67.27 per cent with a genetic advance of 7.55 was noticed for this character.

4.3.9 Adult emergence per earhead

The genotypic variance for this trait was 48.48 and phenotypic variance was 88.00. The percentage values for GCV and PCV were 21.73 and 29.28, respectively.

Moderate heritability of 55.06 with a genetic advance of 10.64 was recorded for this character.

4.3.10 Earhead weight per plant

The magnitude of phenotypic and genotypic variances for this character were 35.21 and 20.23, respectively. Phenotypic coefficient of variability was 22.23 and GCV was 16.83.

Moderate heritability of 57.45 per cent and genetic advance of 7.02 was noticed for the earhead weight per plant.

4.3.11 Grain yield per plant

This character exhibited phenotypic variance of 31.63, while genotypic variance was 24.77. The per cent PCV was 30.31 as against the GCV of 26.82.

Genetic advance was 9.07 but high heritability of 78.31 per cent was recorded.

4.3.12 Hundred grain weight

Genotypic and phenotypic variances were 0.035 and 0.04 respectively. The per cent phenotypic coefficient variability was 11.23 as against the GCV of 10.51.

High heritability 87.5 percentage with a low genetic advance of 0.361 was noticed for this character.

4.4 TAM2566 x SPV813

Phenotypic variance, genotypic variance, phenotypic coefficient of variability, genotypic coefficient of variability, heritability and genetic advance in respect of various characters for the cross TAM 2566 x SPV 813 in F_3 generation are presented in Table 5, Fig. 3 and 4.

4.4.1 Days to 50 per cent flowering

Genotypic variance for days to 50 per cent flowering was 4.05 as against the phenotypic variance of 4.25. The PCV and GCV were 5.31 and 5.27 per cent respectively.

Among all the characters, this trait exhibited highest heritability estimate of 98.60 per cent with the genetic advance estimate of 7.67.

Table 5. Estimates of phenotypic and genotypic coefficients of variability, heritability and genetic advance (GA) in respect of twelve characters in TAM2566 X SPV813

	Day to 50% flowering	Anther colour	No. of midges/ earhead	Glume length (G1)	Glume length (G2)	Eggs/100 florets	larvae/ 100 florets	Per cent grain damage	Adult emergence/ earhead	Earhead wt/p	Grain yield	100 grain weight
PV	14.25	0.65	10.86	0.04	0.030	277.31	126.83	37.47	106.39	91.15	42.10	0.060
GV	14.05	0.44	10.48	0.03	0.025	243.15	111.82	22.64	60.47	67.30	38.73	0.054
PCV	5.31	26.72	48.46	7.04	6.120	49.78	46.63	23.42	33.63	33.40	27.59	11.460
GCV	5.27	21.96	47.60	5.79	5.200	46.62	43.79	18.21	25.36	28.70	26.49	10.690
h^2	98.60	67.69	96.47	75.00	83.350	87.68	88.17	60.41	56.84	73.83	91.99	83.330
GA	7.67	1.33	6.55	0.30	0.290	30.08	20.45	7.62	12.08	14.52	12.29	0.410
GAM	10.78	44.31	96.31	10.33	9.590	89.92	84.70	29.51	39.38	50.80	52.30	19.930

PV - Phenotypic variance;
 GV - Genotypic variance;
 PCV - Phenotypic coefficient of variation;
 GCV - Genotypic coefficient of variability;
 h^2 - Broad-sense heritability;
 GA - Genetic advance;
 GAM - Genetic advance over mean

4.4.2 Anther colour

The phenotypic variance was 0.65 and that of GV was 0.44. The PCV (26.72%) and GCV (21.96%) were moderate for this character.

It is evident from the table that heritability (67.69%) was moderate with genetic advance of 1.33.

4.4.3 Number of adult midges per earhead

The genotypic variance was 10.48 while phenotypic variance was 10.86 for number of midges per earhead. Phenotypic coefficient of variability was 48.46 per cent while GCV was 47.60 per cent.

This parameter also showed high heritability estimate of 96.47 per cent while genetic advance was 6.55.

4.4.4 Glume length G_1

The estimate of phenotypic variance was 0.04 while that of genotypic variance was 0.03. The PCV and GCV were 7.04 and 5.79, respectively.

Genetic advance was 0.30 and the per cent heritability was high (75.00) for this character.

4.4.5 Glume length G_2

The estimate of genotypic variance was 0.025 for glume length- G_2 as against the phenotypic variance of 0.03. The per cent phenotypic coefficient of variability was 6.12 and gcv was 5.20 per cent.

High heritability estimate of 83.35 per cent was recorded for this trait and the estimate of genetic advance was 0.29.

4.4.6 Number of eggs per hundred florets

The number of eggs per hundred florets showed high genotypic variance (243.15) and phenotypic variance (277.31). The phenotypic coefficient of variability was 49.78 per cent as against 46.62 per cent of genotypic coefficient of variability.

High heritability (87.68%) coupled with a genetic advance estimate of 30.08 was noticed for this character.

4.4.7 Number of larvae per hundred florets

This trait showed a PV estimate of 126.83 and gv estimate of 111.82. The gcv was 43.79 per cent while pcv was 46.63 per cent.

Estimate of Genetic advance was 20.45, while estimate of heritability per cent was 88.17.

4.4.8 Per cent grain damage (chaffiness)

This character exhibited genotypic variance of 22.64 and phenotypic variance was 37.47. The per cent genotypic coefficient of variability was 18.21 as against phenotypic coefficient variability of 23.42.

While the genetic advance for this character was low (7.62), the heritability was moderately high (60.41%).

4.4.9 Adult emergence per earhead

The phenotypic and genotypic variances for this parameter were 106.39 and 60.47, respectively. While the genotypic coefficient of variability was 25.36 per cent, the PCV was 33.63 per cent.

This trait recorded moderate heritability of 56.84 with a Genetic advance of 12.08.

4.4.10 Earhead weight per plant

The values for phenotypic and genotypic variances were 91.15 and 67.30, respectively. The per cent genotypic coefficient of variability was 28.70 as against the phenotypic coefficient of variability of 33.40.

Earhead weight showed a heritability estimate of 73.83 per cent with a genetic advance of 14.52.

4.4.11 Grain yield per plant

The genotypic and phenotypic variance for this character were low, while the PCV and GCV were 27.59 and 26.49, respectively.

Heritability was very high (91.99%) while genetic advance was 12.29.

4.4.12 Hundred grain weight

As indicated in the table, the phenotypic variance was very low (0.06) and so did the GV (0.05). The GCV and PCV were 10.69 and 11.46, respectively.

Hundred grain weight showed high heritability estimate of 83.33 per cent while genetic advance was only 0.41.

4.5 TAM2566 x SPV829

Phenotypic variance, genotypic variance, phenotypic coefficient of variability, genotypic coefficient of variability, heritability and genetic advance in respect of different parameters for the cross TAM2566 x SPV829 in F_3 generation are presented in table 6, Fig. 5 and 6.

Table 6. Estimates of phenotypic and genotypic coefficients of variability, heritability and genetic advance (GA) in (GA) in respect of twelve characters in TAM2586 x SPV829

	Day to 50% flowering	Anther colour	No. of midges/ earhead	Glume length (G1)	Glume length (G2)	Eggs/100 florets	larvae/ 100 florets	Per cent grain damage	Adult emergence/ earhead	Earhead wt/p	Grain yield	100 grain weight
PV	15.60	1.68	21.13	0.050	0.050	212.46	172.41	41.56	167.50	150.30	143.61	0.05
GV	15.33	1.41	16.93	0.046	0.046	187.60	154.38	26.09	123.95	133.82	137.27	0.04
PCV	5.64	35.70	51.94	6.680	6.650	53.67	47.57	23.19	37.41	26.85	38.16	9.33
GCV	5.59	32.71	46.50	6.421	6.460	50.43	45.02	18.37	32.22	25.34	37.31	8.67
h^2	98.24	83.92	80.14	92.000	92.000	88.30	89.54	62.78	74.20	89.04	95.58	80.00
GA	7.99	2.24	7.59	0.420	0.423	26.51	24.22	8.34	19.76	22.49	23.59	0.36
GAM	11.42	61.73	85.75	12.660	12.760	97.62	87.75	29.99	57.18	49.25	75.14	14.72

PV - Phenotypic variance;
GV - Genotypic variance;
PCV - Phenotypic coefficient of variation;
GCV - Genotypic coefficient of variability;
 h^2 - Broad-sense heritability;
GA - Genetic advance;
GAM - Genetic advance over mean

4.5.1 Days to 50 per cent flowering

The values of 15.60 and 15.33 were recorded as phenotypic and genotypic variance, respectively. The per cent genotypic and phenotypic coefficient of variability were 5.59 and 5.64.

Genetic advance estimate was 7.99. High heritability (98.24%) was recorded for this character.

4.5.2 Anther colour

The variances 1.41 (PV) and 1.68 (GV) were recorded for anther colour. The genotypic coefficient of variability was 32.71 as against the PCV of 35.70.

The value for genetic advance was low (2.24), heritability was very high (83.92%).

4.5.3 Number of adult midges per earhead

As observed from the table the phenotypic variance was 21.13 and genotypic variance was 16.93. The PCV (51.94%) and GCV (46.50%) values were moderate.

The per cent heritability value was 80.14, while genetic advance was 7.59.

4.5.4 Glume length - G_1

This parameter exhibited a very low genotypic and phenotypic variance 0.046 and of 0.05, respectively. The PCV was 6.68 per cent and that of GCV was 6.421. High heritability of 92.0 per cent with a genetic advance estimate of 0.42 was recorded for glume length.

4.5.5 Glume length - G_2

The trait glume length- g_2 showed phenotypic and genotypic variances of 0.046 and 0.05, respectively. The phenotypic coefficient of variability was 6.65 per cent as against the genotypic coefficient variability of 6.460 per cent.

Genetic advance was 0.42. High heritability of 92 per cent was recorded for this character.

4.5.6 Number of eggs per hundred florets

It is this character which showed highest variance estimates among all characters as revealed from the values of 212.46 for PV and 187.60 for GV. The phenotypic and genotypic coefficient of variability was 53.67 and 50.43 per cent, respectively.

This trait manifested high heritability (88.30%) with a moderate genetic advance of 26.51.

4.5.7 Number of larvae per hundred florets

This parameter also exhibited high genotypic and phenotypic variance values of 154.38 and 172.41 respectively. Phenotypic coefficient of variability was 47.57 and GCV was 50.02.

Genetic advance was 24.22 with a high heritability (89.54%).

4.5.8 Per cent grain damage (chaffiness)

The genotypic variance for per cent grain damage was 26.09 and to that of phenotypic variance was 41.56. The phenotypic coefficient of variability was 23.19 as against genotypic coefficient of variability of 18.37 per cent.

Per cent grain damage showed genetic advance of 8.34 while heritability estimate was 62.78 per cent.

4.5.9 Adult emergence per earhead

Highest phenotypic variance of 167.05 as against genotypic variance of 123.95 was recorded for this parameter. The PCV and GCV values were 37.41 and 32.32, respectively.

Estimates of heritability was 74.20 per cent and Genetic advance was 19.76.

4.5.10 Earhead weight per plant

A very high variance estimates of 150.30 for PV and (133.82) for GV were noticed for earhead weight per plant. The GCV was 25.34 and PCV was 26.85.

The estimate of heritability was 89.04 high and genetic advance was 22.49.

4.5.11 Grain yield per plant

Grain yield per plant also showed high genotypic (137.27) and phenotypic (143.61) variances. The phenotypic coefficient of variability was 38.16 per cent as against the gcv 37.31.

Genetic advance was 23.59 for this character and estimate of heritability was 95.58.

4.5.12 Hundred grain weight

The values 0.05 and 0.04 were recorded as phenotypic and genotypic variances, respectively. The GCV was 8.67 and PCV was 9.33.

Heritability was high (80.00%) and estimate of genetic advance was 0.36.

4.6 Phenotypic and Genotypic correlation studies among different characters in the cross, DJ 6514 x SPV 829

Correlation coefficient between pairs of characters worked out at phenotypic and genotypic level are presented in Table 7.

Although number of days to fifty percent flowering showed no significant correlation with any of the character both phenotypically and genotypically, exhibited positive phenotypic correlation with number of midges per earhead (+0.1126), glume length- g_1 (+0.2208) glume length- g_2 (+0.2216), eggs per hundred florets (+0.1804), larvae per hundred florets (+0.1449) and per cent grain damage (+0.2003). Its association with anther colour (+0.0687) and hundred grain weight (+0.0574) was positive but weak. It showed negative phenotypic correlation with earhead midge emergence, earhead weight and grain yield weight and their values were -0.0214, -0.0679 and - 0.0576, respectively. Genotypic association of this trait found positive with percentage grain damage (+0.2464), g_1 (+0.2228), g_2 (0.2236), eggs per hundred florets (+0.2001), larva per hundred florets (+0.1571), number of adult midges per earhead (+0.1656) and anther colour (+0.1117) and very low correlation with hundred grain weight (+0.0669). Negative association was noticed with grain yield per plant

Table 7. Estimates of phenotypic and genotypic correlation of different characters with per cent grain damage by *C. sorghicola* (Coq.) in DJ6514 x SPV829 cross

Plant and insect parameters	Anther colour	No. of midges/earhead	G1	G2	Eggs/100 florets	larvae/100 florets	Adult midge emergence	Earhead weight	Grain yield weight	100 grain weight	Per cent grain damage (dependent)
Days to 50% Flowering	0.0687	0.1126	0.2208	0.2216	0.1804	0.1449	-0.0214	-0.0679	-0.0576	0.0574	0.2003
Anther colour	0.1117	0.1656	0.2228	0.2236	0.2001	0.1571	-0.0214	-0.1214	-0.1535	0.6669	0.2464
	-	0.1180	-0.2001	-0.1765	-0.0265	-0.0282	-0.0292	0.1784	0.0880**	0.0206	0.0341
	-	0.2772*	-0.3324**	0.2843*	-0.0469	-0.0488	-0.0635	0.5076**	0.3741	0.0383	0.0670**
No. of midges/earhead		-	0.0981	0.0820	0.5198**	0.4217**	0.1095	-0.3001*	-0.2115	-0.0416	0.3854**
		-	0.1358	0.1196**	0.8330**	0.6611**	0.2752*	-0.7733**	-0.8141**	-0.0701	0.6853**
G1			-	0.9183**	0.2066	0.1542	-0.0194	-0.1599	-0.0840	0.0752	0.1992
G2			-	0.9183**	0.2271	0.1657	-0.0206	-0.2825*	-0.2216	0.0869	0.2429
			-	-	0.1918	0.1388	-0.0153	-0.1541*	-0.1050	0.0731	0.1900
			-	-	0.2271	0.1657	-0.0206**	-0.2825**	-0.2216**	0.0869	0.2429**
Eggs/100 florets				-	-	0.7966**	0.3168**	-0.4757**	-0.3874**	0.0735	0.7660**
				-	-	0.9409	0.4691**	-0.9235**	-1.1237**	0.0933	1.0265**
Larvae/100 florets					-	-	0.4530**	-0.6254**	-0.4644**	0.0190	0.9186**
					-	-	0.6731**	-1.1876**	-1.3176**	0.0236	1.2039**
Earhead midge emergence							-	-0.2755*	-0.3181**	0.1350	0.3942**
							-	-0.6558**	-0.7757**	0.2101	0.7277**
Earhead weight								-	0.5483**	0.0939	-0.5756**
								-	1.5569**	0.1915	-1.2399**
Grain yield weight									-	0.0848	-0.4125**
									-	0.2585*	-1.3275**
100 grain weight										-	0.0715
										-	0.1007

** - Significant at 1% level

* - Significant at 5% level

(-0.1539), earhead weight per plant (-0.1210) and midge emergence per earhead (-0.0214).

The phenotypic correlation of the anther colour was not significant with any of the traits. It showed positive correlation with number of midges per earhead (+0.1182) and earhead weight (+0.1784). However with grain yield, hundred grain weight and per cent grain damage, it exhibited very low positive correlation and their values were +0.0880, +0.0206, and +0.0341, respectively. The negative correlation of this character was found with glume length- g_1 (-0.2001), glume length- g_2 (-0.1765), eggs per hundred florets (-0.02605) and earhead midge emergence (-0.0292). The correlation of this trait at genotypic level found significant and positive with earhead weight (+0.5076), grain yield weight (+0.3741), number of midges per earhead (+0.2772) and negatively with g_1 (-0.3224) and g_2 (-0.2843). The association of this trait with hundred grain weight (+0.0303), per cent grain damage (+0.0670) was positive but nonsignificant and with adult emergence (-0.0635), eggs per hundred florets (-0.0469) and with larva per hundred florets (-0.0488) was negative.

Number of adult midges per earhead showed positively significant phenotypic correlation with eggs per hundred

florets (+0.5198), larvae per hundred florets (+0.4217) and percentage grain damage (+0.3854). Its association with earhead midge emergence was positive but not significant (+0.1095). With glume length g_1 (+0.0931) and glume length $-g_2$ (+0.0820), it recorded very low positive correlation. Negatively significant association of this trait was found with earhead weight (-0.3001), while with grain yield weight (-0.2115) and hundred grain weight (-0.0416), it was negative but not significant.

Significantly high and positive correlation of this parameter at genotypic level was found with eggs per hundred florets (+0.8330), percentage grain damage (+0.6853), larva per hundred florets (+0.6611) and with midge emergence per earhead (+0.2752), while its association was significantly negative with grain yield per plant (-0.8141) and earhead weight (-0.7733). It showed non significant positive association with g_1 (+0.1358), g_2 (+0.1196) and negative association with hundred grain weight.

The glume length- g_1 exhibited positive and highly significant correlation at phenotypic and genotypic level with glume length $-g_2$ (+0.9183). However, its phenotypic association with eggs per hundred florets (+0.2066), larvae

per hundred florets (+0.1542) and per cent grain damage (+0.1992) were only positive but not significant and with hundred grain weight was positively low (+0.0752). This trait expressed negative and not significant correlation with earhead weight (-0.1599), grain yield weight (-0.0840) and midge emergence (-0.0194). Negatively significant genotypic association of this trait was found with earhead weight per plant (-0.2825), while non significant with grain yield per plant (-0.2216) and midge emergence per earhead (-0.0206). The correlation with percentage grain damage (+0.2429), eggs per hundred florets (+0.2271), larva per hundred florets (+0.1657) and with hundred grain weight (+0.0869) at genotypic level was positive but not significant.

The phenotypic correlation of the glume length- g_2 was not found significant with all 9 of the characters except glume length- g_1 . However, it exhibited positive correlation with eggs per hundred florets (+0.1918), larvae per hundred florets (+0.1388), percentage grain damage (+0.1900) and very low positive correlation (+0.0731) with hundred grain weight. Negatively non significant association of this trait was seen with earhead weight (-0.1541), grain yield per plant (-0.1050) and with adult emergence (-0.0153). At genotypic level, it indicated negatively significant association with earhead

weight (-0.2722) and grain yield weight (-0.2773). While non significant with adult emergence (-0.0315). Its high association with percent grain damage (+0.2316) and eggs per hundred florets (+0.2107) was positive but not significant.

The number of eggs per hundred florets showed highly positive and significant phenotypic correlation with number of larvae per hundred florets (+0.7966), per cent grain damage (+0.7660) and earhead midge emergence (+0.3168), while its association with hundred grain weight was positive but not significant (+0.0731). With earhead weight and grain yield weight, it exhibited negatively significant correlation and their values were - 0.4757 and - 0.3874 respectively.

Positive and significantly high genotypic correlation of eggs per hundred florets was noticed with larvae per hundred florets (+0.9409), earhead midge emergence (+0.4691) and per cent grain damage (+1.0265), but was non significant with hundred grain weight (+0.093). It had significantly negative association with earhead weight (-0.9225) and grain yield weight (-1.1237).

The number of larvae per hundred florets exhibited positive and significant phenotypic correlation with per cent grain damage and earhead midge emergence. While its

association with former trait was very high (+0.9186), and it was moderate (+0.4530) with latter trait. Significantly negative correlation was noticed with earhead weight (-0.6254) and grain yield weight (-0.4644). Non significant association with hundred grain weight (+0.0190) was evident. It exhibited highly significant and positive genotypic correlation with adult emergence per earhead (+0.6760) and per cent grain damage (+1.2039), while it was significantly negative with earhead weight (-1.1876) and grain yield per plant (-1.3176). Positively non significant very low correlation noticed with hundred grain weight (+0.0236).

The phenotypic correlation of earhead midge emergence was significantly positive with per cent grain damage (+0.3942) and was positive but not significant with hundred grain weight (+0.1350), while negatively significant association was found with earhead weight (-0.2755) and grain yield weight (-0.3181). While significantly positive genotypic correlation was recorded with per cent grain damage (+0.7277), it was not significant with hundred grain weight (-0.2101). Negative significant association was noticed with earhead weight per plant (-0.6558) and grain yield per plant (-0.7757).

Earhead weight per plant exhibited significant and positive genotypic correlation with grain yield (+0.5483) and negative correlation (-0.5756) with per cent grain damage, its association with hundred grain weight was positively low (+0.0939). Its genotypic correlation was significantly positive with grain yield per plant (+1.5561), it was significantly negative with per cent grain damage (-1.2399). With hundred grain weight it had positively non significant association of +0.1915.

The grain yield per plant showed significantly negative phenotypic correlation with per cent grain damage (-0.4125) and low non significant positive correlation (+0.0848) with hundred grain weight. Its genotypic association was found to be significantly positive with hundred grain weight (+0.2585) and significantly negative with per cent grain damage (-1.3275).

Very low non significant association at phenotypic and genotypic level between hundred grain weight and percent grain damage were recorded and the values were +0.0715 and 0.1007 respectively.

4.7 Phenotypic and genotypic correlation in F_3 population of cross TAM2566 x SPV813

Phenotypic and genotypic correlation among different characters in a cross TAM2566 x SPV813 in F_3 generation are presented in Table 8.

The days to fifty percent flowering expressed significant positive correlation at phenotypic level with number of adult midges per earhead (+0.4725), anther colour (+0.2944), and negative association with glume length- g_1 (-0.3010). Its association was positively nonsignificant with eggs per hundred florets (0.1325) and hundred grain weight (0.1503). This trait showed very low non significant positive association with larvae per hundred florets (0.0143), earhead emergence (0.0535), grain yield per plant (0.0639), earhead weight (0.0343) and negative association with per cent grain damage (-0.0221).

Significantly positive genotypic correlation between days to fifty percent flowering and anther colour (+0.3604) was noticed but degree of relationship was non significant with number of adult midges per earhead (+0.1768), eggs per hundred florets (+0.1425), larvae per hundred florets (+0.0153), adult emergence (+0.0715), earhead weight per plant

Table 8. Estimates of phenotypic and genotypic correlation of different characters with per cent grain damage by *C. sorghicola* (Coq.) in TAM2566 x SPV813 cross

Plant and insect parameters	Anther colour	No. of midges/earhead	G1	G2	Eggs/100 florets	larvae/100 florets	Adult midge emergence	Earhead weight	Grain yield weight	100 grain weight	Per cent grain damage (dependent)
Days to 50% Flowering	0.2944*	0.4725**	-0.3010**	-0.2202	0.1325	0.0143	0.0535	0.0343	0.0639	0.1563	-0.0221
Anther colour	0.3604**	0.1768	-0.3500**	-0.2716*	0.1425	0.0153	0.0715	0.0402	0.0671	0.1724	-0.0282
No. of midges/earhead	-	0.0268	0.0102	0.0881	-0.0334	-0.1179	-0.0163	0.2312	0.2759*	0.0625	-0.0820
G1	-	0.0332	0.0143	0.1311	-0.0433	-0.1526**	-0.0263	0.3271**	0.3497**	0.0832	-0.1310
G2	-	-	0.2335	0.1970	0.7627**	0.6269**	0.1152	-0.2837*	-0.2893*	-0.0223	0.5624**
Eggs/100 florets	-	-	-0.2745	0.2456	0.8291**	0.6797**	0.1468	-0.3361**	-0.3071**	-0.0248	0.7263**
Larvae/100 florets	-	-	-	0.8036**	-0.4104**	-0.3471**	0.0166	0.3971**	0.4185**	0.1730	-0.2288
Earhead midge emergence	-	-	-	1.1365**	-0.5061**	-0.4268**	0.0254	0.5337**	0.5039**	0.2138	-0.3352**
Earhead weight	-	-	-	-	0.0861	0.0240	-0.0422	0.2931*	0.3207**	-0.0040	0.0037
Grain yield weight	-	-	-	-	0.1127	0.0313	-0.0686	0.4170**	0.4095**	-0.0053	-0.1314**
100 grain weight	-	-	-	-	-	0.8758**	0.2584*	-0.5286**	-0.5897**	-0.2651*	0.7722**
	-	-	-	-	-	0.9961**	0.3868**	-0.6569**	-0.6565**	-0.3102*	1.0463**
	-	-	-	-	-	-	0.3244**	-0.6874**	-0.7276**	-0.2073	0.9313**
	-	-	-	-	-	-	0.4736**	-0.8520**	-0.8079**	-0.2419	1.2585**
	-	-	-	-	-	-	-	-0.2748*	-0.2979*	0.0614	0.2770*
	-	-	-	-	-	-	-	-0.3366**	-0.3427**	0.0870	0.4157**
	-	-	-	-	-	-	-	-	0.1138	0.2581*	-0.6616**
	-	-	-	-	-	-	-	-	1.3514**	0.3290**	-0.9770**
	-	-	-	-	-	-	-	-	-	0.3342**	-0.7120**
	-	-	-	-	-	-	-	-	-	0.3817**	-0.9418**
	-	-	-	-	-	-	-	-	-	-	-0.1312
	-	-	-	-	-	-	-	-	-	-	-0.1824

** - Significant at 1% level

* - Significant at 5% level

(+0.0402), grain yield per plant (+0.0671) and hundred grain weight (+0.1724). The association was significantly negative with glume length- g_1 (-0.3500), g_2 (-0.2716) and nonsignificant with percent grain damage (-0.0282).

The phenotypic correlation of anther colour was found positively significant with grain yield weight (+0.2759). Negatively non significant association of this trait was noticed with eggs per hundred florets, larva per hundred florets, earhead midge emergence and per cent grain damage and their values were -0.0334, -0.1179, -0.0163, and -0.0820 respectively. While positively non significant association showed with number of adult midges per earhead (0.0268), g_1 (0.0102), g_2 (0.0881), earhead weight (0.2312) and with hundred grain weight (0.0625).

At genotypic level anther colour indicated significant positive correlation with earhead weight (+0.3271), grain yield per plant (+0.3497) and non significant with number of adult midges per earhead (+0.0332), glume length- g_1 (+0.0143), g_2 (+0.1311), and hundred grain weight (+0.082). Negative not significant association was noticed with eggs per hundred florets, larva per hundred florets,

adult emergence and per cent grain damage and the values were -0.0433, -0.1526, -0.0263, and -0.1310 respectively.

Number of adult midges per earhead exhibited highly significant and positive correlation at phenotypic level with eggs per hundred florets and moderate with larva per hundred florets and per cent grain damage, their values being +0.7627, +0.6269, and +0.5624 respectively. However its association with glume length - g_2 (0.1920) and earhead midge emergence (0.1152) was not significant. It showed negatively significant correlation values of -0.2837 and -0.2893 with earhead weight and grain yield per plant respectively. While negative non significant correlation with glume length- g_1 (-0.2335).

Its association was positive and significant at genotypic level with eggs per hundred florets (+0.8291), larva per hundred florets (+0.6797), per cent grain damage (+0.7263), and significantly negative with earhead weight per plant (-0.3361) and grain yield per plant (-0.3071). Positively non significant association found with glume length - g_2 (+0.2456), adult emergence (+0.1468) and negatively non significant with hundred grain weight (-0.0248).

The phenotypic correlation of glume length- g_1 was found highly significant and positive with glume length- g_2 (+0.8036), while moderate with earhead weight (+0.3971) and grain yield per plant (+0.4185). Its association with hundred grain weight and earhead midge emergence was positive but not significant and their values were 0.1730 and 0.0166 respectively. Negatively significant correlation of this trait was found with number of eggs per hundred florets (-0.4104) and larva per hundred florets (-0.3471), while the value of - 0.2288 was noticed as non significant correlation of this trait with the per centage of damage.

Significantly positive association of glume length- g_1 at genotypic level was found with glume length- g_2 (+1.1365), earhead weight per plant (+0.5337) and grain yield per plant (+0.5039) and non significant with adult emergence (+0.0294) and hundred grain weight (+0.2136). With eggs per hundred florets (-0.5061), larva per hundred florets (-0.4268) and percent grain damage (-0.3352) it exhibited negatively significant association.

The glume length - g_2 showed significantly positive phenotypic correlation with earhead weight (+0.2931) and grain yield weight (+0.3207), while its association was only

positive but not significant with eggs per hundred florets and larvae per hundred florets and their values being 0.0861 and 0.0240 respectively. It had negative non significant association with earhead midge emergence (-0.0422) and hundred grain weight (-0.0040). Its genotypic correlation found positively significant with earhead weight per plant (+0.4174), grain yield per plant (+0.4095) and non significant association with eggs per hundred florets (+0.1127) and larva per hundred florets (+0.0313). Negatively non significant association noticed with adult emergence (-0.0686), hundred grain weight (-0.0093) and percent grain damage (-0.1314).

The phenotypic correlation of number of eggs per hundred florets was found high and positively significant with larvae per hundred florets (+0.8758) followed by per cent grain damage (+0.7722), while with earhead midge emergence it showed moderate association of +0.2584. The values viz., -0.5286, -0.5897 -0.2651 were recorded as significantly negative correlation of this trait with earhead weight, grain yield weight and hundred grain weight was also evident. At genotypic level, it exhibited positive and highly significant association with larvae per hundred florets (+0.9961), adult emergence (+0.3864) and percent grain damage (+1.0463). It exhibited negatively significant association with earhead

weight (-0.6569), grain yield per plant (-0.6565) and hundred grain weight (-0.3102).

The number of larvae per hundred florets showed positive and highly significant correlation at phenotypic level with per cent grain damage of (+0.9313), while its association was moderate with earhead midge emergence (+0.3244). With grain yield (-0.7276) and earhead weight (-0.6874) it exhibited significantly negative correlation. Its genotypic association was found positively significant with adult emergence (+0.4736) and per cent grain damage (+1.2585). The correlation values of -0.8520 and -0.8079 indicated significantly negative association of this trait with earhead weight and grain yield per plant, respectively. Its association was not strong with hundred grain weight (-0.2419).

The phenotypic correlation of the earhead midge emergence was found positively significant with per cent grain damage (+0.2770) and negative with grain yield per plant (-0.2979), while with hundred grain weight its association was very low with a value of +0.0614. The value of -0.2748 indicated as negative and significant association of this trait with earhead weight. At genotypic level, it exhibited

significantly negative correlation with earhead weight (-0.3368), and grain yield per plant (-0.3427). With percent grain damage its association was highly positive with a value of +0.4162 and very low with hundred grain weight (+0.0870).

The earhead weight per plant exhibited moderate and significantly negative phenotypic correlation (-0.6616) with per cent grain damage but low and significantly positive correlation (+0.2581) with hundred grain weight. Its association with grain yield (+0.1138) was not significant. Genotypic correlation was found to be significantly positive with grain yield per plant (+1.3514) and negatively with percent grain damage (-0.9770). With hundred grain weight, its association was significant and positive with a value of +0.3290.

The phenotypic correlation of grain yield per plant exhibited moderately positively significant correlation with hundred grain weight (+0.2581) and negative and high significant association with per cent grain damage (-0.7120). Genotypic association of this trait was significantly positive with hundred grain weight (+0.3817) and significantly negative with per cent grain damage (-0.9418).

The values of - 0.1312 and - 0.1824 found as negatively non significant association between hundred grain weight and percent grain damage at both phenotypic and genotypic level.

4.8 The correlation studies between different characters in F_3 generation of a cross TAM2566 x SPV829

As indicated in the table 9 the phenotypic correlation between days to fifty percent flowering although showed no significant correlation and the any of the characters, it exhibited positive association with number of adult midges per earhead (+0.2418), anther colour (+0.1754), earhead weight (+0.116) and grain yield weight (+0.1198). Similarly it also showed positive association with glume length - g_1 , g_2 , and earhead midge emergence with a very low values of +0.0585, +0.0152 and of +0.0116, respectively. It exhibited negative but not significant correlation with eggs per hundred florets (-0.1604), larvae per hundred florets (-0.1193), hundred grain weight (-0.0249) and per cent grain damage (-0.2392).

At genotypic level, days to fifty per cent exhibited significantly positive association with number of adult midges per earhead (+0.2725) and negative with per cent grain damage

Table 9. Estimates of phenotypic and genotypic correlation of different characters with per cent grain damage by *C. sorghicola* (Coq.) in TAM2566 x SPV829 cross

Plant and insect parameters	Anther colour	No. of midges/earhead	G1	G2	Eggs/100 florets	larvae/100 florets	Adult midge emergence	Earhead weight	Grain yield weight	100 grain weight	Per cent grain damage (dependent)
Days to 50% Flowering	0.1754	0.2418	0.0585	0.0152	-0.1604	-0.1193	0.0116	0.1116	0.1198	-0.0249	-0.2323
Anther colour	-0.1414	0.2725*	0.0590	-0.1722	-0.1272	0.0469	0.0136	0.1236	-0.0236	-0.0252	-0.2965
	-	0.0019	-0.0072	0.0166	-0.0110	0.0454	0.0453	-0.0936	-0.1104	-0.0501	0.0892
No. of midges/earhead	-	-0.0050	-0.0168	0.0390	-0.0277	0.1125	0.1233	-0.2326	-0.2649*	-0.1176	0.2648
	-	-	-0.0711	-0.1117	0.2569*	0.2745*	0.2661	-0.2559*	-0.2669*	-0.2421*	0.1093
	-	-	-0.0794	-0.1248**	0.3054*	0.3240**	0.3375**	-0.3030*	-0.3050*	-0.2704*	0.1545
G1	-	-	-	0.9779	-0.0623	-0.0336	0.0105	-0.0849	-0.1805	-0.0398	-0.0736
G2	-	-	-	0.9779**	-0.0663	-0.0355	0.0120	-0.0900	-0.1846	-0.0398	-0.0937
Eggs/100 florets	-	-	-	-	0.0464	0.0518	0.0356	-0.1046	-0.2010	-0.0312	0.0075
Larvae/100 florets	-	-	-	-	0.0494	0.0547	0.0413	-0.1109	-0.2056	-0.0312	0.0095
	-	-	-	-	-	0.9566**	0.3944**	-0.6391**	-0.6144**	-0.0738	0.8522**
	-	-	-	-	-	1.0758**	0.4513**	-0.7208**	-0.6687**	-0.0785	1.1478**
Earhead midge emergence	-	-	-	-	-	-	0.3842**	-0.7138**	-0.8743**	-0.0875	0.8871**
	-	-	-	-	-	-	0.4312**	-0.7995**	-0.7505**	-0.0924	1.1864**
Earhead weight	-	-	-	-	-	-	-	-0.3686**	-0.1793	0.0279	0.3558**
	-	-	-	-	-	-	-	-0.3866**	-0.2129**	0.0324	0.4857**
Grain yield weight	-	-	-	-	-	-	-	-	0.9526**	0.2123	-0.5939**
	-	-	-	-	-	-	-	-	1.0326	0.2250	-0.7965**
100 grain weight	-	-	-	-	-	-	-	-	-	0.1932	-0.5648**
	-	-	-	-	-	-	-	-	-	0.1977	-0.7311**
	-	-	-	-	-	-	-	-	-	-	-0.1924
	-	-	-	-	-	-	-	-	-	-	0.2435

** - Significant at 1% level

* - Significant at 5% level

(-0.2965). With anther colour, glume length- g_2 , earhead weight per plant, grain yield per plant and hundred grain weight, it exhibited negative and non significant correlation with values of - 0.1414, - 0.1722, - 0.1272, - 0.0236, and -0.0252, respectively. Positively non significant correlation noticed with glume length - g_2 (-0.0576), larva per hundred florets (+0.0469), earhead midge emergence (+0.0136) and earhead weight per plant (+0.1236).

The phenotypic association of anther colour was not found to be significant with any of the characters. It showed positive correlation values of +0.0453, +0.0892, +0.0454 and +0.0166 with the traits viz., earhead midge emergence, per cent grain damage, larva per hundred florets and glume length- g_2 respectively. It exhibited negative association with characters such as; number of adult midges per earhead (-0.0019), glume length - g_2 (-0.0072), eggs per hundred florets (-0.0110), earhead weight (-0.0936), grain yield per plant (- 0.1104) and with hundred grain weight (-0.0501). Genotypic correlation of this trait found positively significant with percent grain damage (+0.2648) and negatively with grain yield per plant (-0.2649). Its association with number of adult midges per earhead, g_2 , eggs per hundred florets and hundred grain weight found negatively non

significant with values of -0.0650, -0.0168, 0.0277, -0.2326 and -0.1176 respectively. Positively non significant correlation noticed with g_2 (+0.0390), larvae per hundred florets (+0.1125) and adult emergence (+.1263).

The number of adult midges per earhead showed significantly positive phenotypic association with eggs per hundred florets (+0.2569), larval per hundred florets (+0.2745) and adult emergence (+0.2661), while its association with the per cent grain damage (+0.1093) was positive and not significant. Although it exhibited negatively non significant correlation with glume length - g_1 (-0.0711), g_2 (-0.1117) and hundred grain weight (-0.2421), but it expressed significant negative association with earhead weight and grain yield weight and their values were -0.2559 and -0.2669 respectively. Significant and positive association at genotypic level noticed with number of eggs per hundred florets (+0.3054), larvae per hundred florets (+0.3240) and adult emergence (+0.3775) and non significant with percent grain damage (0.1543). Negatively significant values of -0.3030, -0.3050, -0.2704 were recorded for earhead weight, grain yield per plant, hundred grain weight and nonsignificant with a values of -0.0794 and - 0.1248 noticed for g_2 and g_2 respectively.

The phenotypic association of glume length - g_1 was found positive and highly significant with glume length - g_2 and the magnitude of association between two traits was +0.9779, while with earhead midge emergence it was non significant (+0.0105). Similarly its association was negative but not significant with the traits eggs per hundred florets, larvae per hundred florets, earhead weights, grain yield per plant, hundred grain weight and per cent grain damage. At genotypic level its association found highly significant with glume length - g_2 (+0.9779) and not significant with earhead midge emergence (+0.0120). With other traits viz; eggs per hundred florets, larvae per hundred florets, earhead weight, grain yield per plant and hundred grain weight, it indicated negatively non significant association with a values of -0.063, -0.0355, - 0.0900, -0.1846, -0.0396 and -0.0931 respectively.

The association of glume length- g_2 at both phenotypic and genotypic level was not found significant with any of the parameters. It expressed positively low phenotypic association with traits viz., eggs per hundred florets (+0.0464), larvae per hundred florets (+0.0518), earhead midge emergence (+0.0356) and with per cent grain damage (+0.0075), while negatively low association with earhead weight (-

0.1046), grain yield per plant (-0.2016) and with hundred grain weight (0.0312). At genotypic level its association found positively non significant with eggs per hundred florets (+0.0494), larvae per hundred florets (+0.0547), earhead midge emergence (+0.0413) and percent grain damage (+0.0095), while negatively non significant with earhead weight per plant (-0.1109), grain yield per plant (-0.2056) and hundred grain weight (-0.0312).

The number of eggs per hundred florets found to have highly significant and positive association phenotypically with larvae per hundred florets (+0.9566), per cent grain damage (+0.8522) followed by earhead midge emergence (+0.3944). In contrast it expressed significantly negative association with earhead weight (-0.6391) and grain yield per plant (-0.6144). While with hundred grain weight negatively non significant association was noticed and the value being - 0.0738. It exhibited highly significant positive association at genotypic level with larvae per hundred florets (+1.0758), per cent grain damage (+0.1478), earhead midge emergence (+0.4513) and negatively with earhead weight per plant (-0.7208), grain yield per plant (-0.6687) while negatively non significant with hundred grain weight (-0.0785).

The phenotypic association of larvae per hundred florets showed highly significant and positive association with per cent grain damage (+0.8871) and earhead midge emergence (+0.3842). Negatively significant correlation of this trait was found with earhead weight (-0.7138) and grain yield per plant (-0.6943), while with hundred grain weight its association was negative but not significant (-0.0875). It exhibited positive and highly significant association at genotypic level with earhead midge emergence (+0.4312) and percent grain damage (+1.1864). The association was significantly negative with earhead weight per plant (-0.7995) and grain yield per plant (-0.7505). With hundred grain weight its association was negatively low (-0.0924).

The phenotypic association between earhead midge emergence and per cent grain damage was positively significant with a value of +0.3558, while with hundred grain weight, it exhibited positive but not significant association (+0.0279). With the earhead weight (-0.3686) and grain yield per plant (-0.1793) it expressed significantly negative association. Its genotypic association was significantly negative with earhead earhead weight per plant (-0.3866), grain yield per plant (-0.2129) and positively with per cent grain damage

(+0.4857). With hundred grain weight it exhibited positively low association (+0.0324).

The phenotypic correlation between earhead weight and grain yield per plant was highly significant and positive, but with the per cent grain damage it was significantly negative (- 0.5939) and not significant with hundred grain weight. At genotypic level its association was found to be significantly positive with grain yield per plant (+1.0326), negative with per cent grain damage (-0.7965) and positive but not significant with hundred grain weight.

The association of grain yield with the per cent grain damage at phenotypic level was significantly negative (-0.5648) and positively non significant with hundred grain weight (+0.1932). Its genotypic correlation was positive but not significant with hundred grain weight (+0.1977) and negative significant with per cent grain damage (-0.7311).

Hundred grain weight exhibited not significant association phenotypically (-0.1924) and genotypically (+0.2435).

4.9 Path coefficient analysis

4.9.1 DJ 6514 x SPV 829

Direct and indirect effects of different characters on per cent grain damage (chaffiness) in F population of

Table 10. Direct and indirect effects of different characters on percentage damage by *C. sorghicola* (Coq.) in a cross DJ6514 x SPV829

Plant and insect parameters	Day to 50% flowering	Anther colour	No. of midges/earhead	G1	G2	Eggs/100 florets	larvae/100 florets	Earhead midge emergence	Earhead weight	Grain yield	100 grain weight	Percentage of damage (dependent)
Days to 50% Flowering	<u>0.0412</u>	0.0051	-0.0047	-0.0000	0.0115	0.0152	0.1263	0.0014	0.0027	-0.0012	0.0029	0.2003
Anther colour	0.0028	<u>0.0744</u>	-0.0049	0.0000	-0.0092	-0.0022	-0.0246	0.0019	-0.0070	0.0018	0.0010	0.0341
No. of midges/earhead	0.0046	0.0088	<u>-0.0419</u>	-0.0000	0.0043	0.0438	0.3675	-0.0071	0.0118	-0.0043	-0.0021	0.3854
G1	0.0091	-0.0149	-0.0039	<u>-0.0001</u>	0.0476	0.0174	0.1344	0.0013	0.0063	-0.0017	0.0038	0.1992
G2	0.0091	-0.0131	-0.0034	-0.0001	<u>0.0518</u>	0.0162	0.1210	0.0010	0.0061	-0.0021	0.0037	0.1900
Eggs/100 florets	0.0074	-0.0020	-0.0218	-0.0000	0.0099	<u>0.0843</u>	0.6942	-0.0207	0.0188	-0.0079	0.0037	0.7660
Larvae/100 florets	0.0060	-0.0021	-0.0177	-0.0000	0.0072	0.0672	<u>0.8714</u>	-0.0295	0.0247	-0.0095	0.0010	0.9186
Earhead midge emergence	0.0013	-0.0031	-0.0065	0.0000	-0.0011	0.0381	0.5636	<u>-0.0457</u>	0.0155	-0.0064	0.0097	0.5623
Earhead weight	-0.0028	0.0133	0.0126	0.0000	-0.0080	-0.0401	-0.5450	0.0180	<u>-0.0394</u>	0.0112	0.0047	-0.5756
Grain yield weight	-0.0024	0.0066	0.0089	0.0000	-0.0054	-0.0327	-0.4047	0.0142	-0.0216	<u>0.0204</u>	0.0042	-0.4125
100 grain weight	0.0024	0.0015	0.0017	-0.0000	0.0038	0.0062	0.0166	-0.0088	-0.0037	0.0017	<u>0.0501</u>	0.0715

cross DJ6514 x SPV829 were studied through path coefficient analysis and the results are furnished in Table 10.

4.9.1 Days to fifty per cent flowering

The direct effect of this trait on per cent grain damage was found to be very negligible. It showed slight positive indirect effect through number of larvae per hundred florets on chaffiness. Its positive indirect effects through anther colour, glume length- g_2 , eggs per hundred florets, adult emergence, earhead weight, and hundred grain weight were also found to be very less. Through number of midges per earhead, grain yield per plant and glume length - g_1 , it exhibited negative indirect effects; while with former two traits its effects were very less, there was no effect on the last.

4.9.2 Anther colour

The direct contribution of anther colour on per cent grain damage was positive but very low. It also showed very low positive indirect effects through flowering, adult emergence, grain yield per plant and hundred grain weight. Its positive indirect effect through glume length g_1 was zero. Very negligible negative contribution of anther colour was noticed through number of adult midges, glume length g_2 , eggs

per hundred florets, larvae per hundred florets and earhead weight per plant.

4.9.3 Number of adult midges per earhead

As revealed in the table although total correlation of this character with per cent grain damage was positively significant, it showed very low negative direct effects on chaffiness.

Its negative indirect effects were negligible through adult emergence per earhead, grain yield per plant and hundred grain weight and nil through glume length - g_1 . Positively very low indirect effects were also noticed through days to fifty per cent flowering, anther colour, glume length- g_2 , number of eggs per hundred florets, and earhead weight per plant. But it showed highly positive but moderately indirect effect through number of larvae per hundred florets.

4.9.4 Glume length - G_1

This character also showed very negligible direct effect on per cent grain damage. However, it revealed positive but low indirect effect through larvae per hundred florets. Positive but negligible indirect contribution were noticed through many traits viz., days to fifty per cent

flowering, glume length- g_2 , eggs per hundred florets, adult emergence per earhead, earhead weight and hundred grain weight. Through anther colour, number of adult midges per earhead and grain yield per plant, this trait exhibited negative indirect effects on per cent grain damage.

4.9.5 Glume length - G_2

This trait revealed very low positive direct effect on per cent grain damage. It also showed low indirect positive effects, through larvae per hundred florets, besides exhibiting very negligible positive indirect contribution through days to fifty per cent flowering, eggs per hundred florets, adult emergence per earhead, earhead weight and hundred grain weight. Negative indirect effects were also noticed through anther colour, number of adult midges per earhead, grain yield per earhead and glume length- g_1 .

4.9.6 Eggs per hundred florets

Even though this trait showed positively high total correlation, it had a very low positive direct effect on per cent grain damage. But its indirect contribution through larvae per hundred florets was highly positive. Very negligible positive indirect effects were registered through days to fifty per cent flowering glume length- g_2 , earhead

weight. Negative indirect effects were noticed through anther colour, number of adult midges per earhead, adult emergence per earhead and grain yield per plant. No effect of this trait was found through glume length- g_1 .

4.9.7 Larvae per hundred florets

It is this character which registered positively high direct effect on per cent grain damage and its total correlation was also found highly significant. Indirect positive contribution of this trait was noticed through days to fifty per cent flowering, glume length - g_2 , earhead weight and grain yield weight. Indirect negative contribution of this trait through anther colour, number of adult midges per earhead, adult emergence per earhead and hundred grain weight were noticed. Its indirect effect through glume length - g_1 was negatively nil.

4.9.8 Adult emergence per earhead

Although it showed positively high total correlation, it exhibited very low negative direct effect on per cent grain damage. However, its indirect effect through larvae per hundred florets was highly positive. Through different traits viz; days to 50 per cent flowering, eggs per hundred florets, earhead weight per plant and hundred grain

weight, it contributed positively very low indirect effect. Negligible negative indirect contribution through anther colour, number of adult midges per earhead, glume length - g_2 and grain yield per plant were found. The effect of this trait was not significant through glume length - g_1 .

4.9.9 Earhead weight per plant

The direct effect of this trait on per cent grain damage was negative but negligible. Very low negative indirect contributions were also found through days to 50 per cent flowering, glume length - g_2 , eggs per hundred florets, while through larvae per hundred florets it showed high indirect effect. A very low positive indirect contributions were noticed through anther colour, number of adult midges per earhead, adult emergence per earhead, grain yield per plant and hundred grain weight. This character also showed no effect on chaffiness through glume length - g_1 .

4.9.10 Grain yield per plant

It expressed very low positive direct effect on chaffiness, while it showed moderately negative indirect contribution through larvae per hundred florets. Negatively indirect effects, but very negligible were noticed through days to 50 per cent flowering, glume length g_2 , eggs per

hundred florets, and earhead weight per plant. This trait also exhibited positively negligible indirect effect via, anther colour, number of adult midges per earhead, adult emergence per earhead and hundred grain weight. Similarly through glume length - g_1 , no effect was observed on chaffiness from this character.

4.9.11 Hundred grain weight

This trait showed positively very low direct effect on chaffiness. Its effect on chaffiness indirectly through other traits viz; days to 50 per cent flowering, anther colour, number of adult midges per earhead, glume length - g_2 , eggs per hundred florets, grain yield per plant and hundred grain weight was also negligible. Very low negative indirect effects were found through adult emergence per earhead and earhead weight per plant.

4.10 TAM 2566 x SPV 813

Results on the Direct and indirect relationship of different characters on a dependent trait per cent grain damage in F_3 generation of the cross TAM2566 x SPV 813 are presented in table 11.

Table 11. Direct and indirect effects of different characters on percentage damage by *C. sorghicola* (Coq.) in a cross TAM2566 x SPV813

Plant and insect parameters	Day to 50% flowering	Anther colour	No. of midges/earhead	G1	G2	Eggs/100 florets	larvae/100 florets	Earhead midge emergence	Earhead weight	Grain yield weight	100 grain weight	Percentage of damage (dependent)
Days to 50% Flowering	-0.0942	0.0421	0.0816	-0.2025	0.1220	0.0268	0.0103	-0.0025	-0.0051	-0.0090	0.0081	-0.0221
Anther colour	-0.0277	0.1440	0.0049	0.0069	-0.0488	-0.0068	-0.0851	0.0008	-0.0344	-0.0389	0.0032	-0.0820
No. of midges/earhead	-0.0421	0.0039	0.1825	-0.1571	-0.1091	0.1543	0.4527	-0.0044	0.0422	0.0408	-0.0012	0.5824
G1	0.0284	0.0015	-0.0426	0.6726	-0.4451	-0.0830	-0.2506	-0.0008	-0.0590	-0.0590	0.0089	-0.0288
G2	0.0208	0.0127	0.0360	0.5405	-0.5539	0.0174	0.0173	0.0019	-0.0436	-0.0452	-0.0002	-0.0037
Eggs/100 florets	-0.0125	-0.0048	0.1392	-0.2760	-0.0477	0.2023	0.6324	-0.0087	0.0786	0.0831	-0.0137	0.7722
Larvae/100 florets	-0.0013	-0.0170	0.1144	-0.2335	-0.0133	0.1772	0.7221	-0.0114	0.1022	0.1026	-0.0107	0.9313
Earhead midge emergence	-0.0091	-0.0042	0.0315	0.0202	0.0423	0.0689	0.3213	-0.0255	0.0586	-0.0631	0.0057	0.4464
Earhead weight	-0.0032	0.0333	-0.0518	0.2671	-0.1624	-0.1069	-0.4964	0.0101	-0.1487	-0.0160	0.0133	-0.6616
Grain yield weight	-0.0060	0.0397	-0.0528	0.2815	-0.1776	-0.1193	-0.5254	-0.0114	-0.0169	-0.1410	0.0173	-0.7120
100 grain weight	-0.0147	0.0090	-0.0041	0.1164	0.0022	-0.0536	-0.1497	-0.0028	-0.0384	-0.0471	0.0517	-0.1312

4.10.1 Days to fifty per cent flowering

The findings in the table reveal that direct effect of this trait on per cent grain damage was negative but very low. Negligible negative indirect contribution also expressed by this parameter through glume length - g_1 , adult emergence per earhead, earhead weight and grain yield per plant. It also showed very low positive indirect contribution via, anther colour, adult midges per earhead, eggs per hundred florets, larvae per hundred florets, hundred grain weight and glume length - g_2 .

4.10.2 Anther colour

The anther colour exhibited low direct effect positively on per cent grain damage. But its indirect effects were positive through adult midges per earhead, glume length - g_1 , adult emergence per earhead, hundred grain weight but negligible. Similarly the effects were negatively very low via days to fifty per cent flowering, glume length G_2 , eggs per hundred florets, larvae per hundred florets, earhead weight and grain yield per plant.

4.10.3 Adult midges per earhead

This trait had moderate total correlation, but it showed low direct contribution on chaffiness. Through eggs

per hundred florets it indicated low indirect positive effect and moderately through larvae per hundred florets. However, negatively low indirect effects were expressed by this trait through glume length - g_1 and glume length - g_2 . Its contribution through all other traits was found to be negligible either negatively or positively.

4.10.4 Glume length - G_1

Although its total correlation was negative and very low, it showed positively moderate direct contribution on per cent grain damage. It also exhibited negatively low indirect effect through larvae per hundred florets and moderately through glume length - g_2 . But its indirect effects were found to be very negligible either positively or negatively via all other traits.

4.10.5 Glume length - G_2

This trait showed negatively moderate direct effect on per cent grain damage and positive indirect contribution through glume length - g_1 . It indicated very low indirect effect either positively or negatively through all other characters.

4.10.6 Eggs per hundred florets

Even this trait had high total correlation, but it expressed low positive direct effect on per cent grain damage. It showed positive indirect effect that was moderately high through larvae per hundred florets. Low negative indirect contribution through glume length - g_1 and positive indirect effect via adult emergence were exhibited by this trait. Through all other parameters, it had negligible indirect effect either positively or negatively.

4.10.7 Larvae per hundred florets

It is this trait which showed positively high direct contribution on per cent grain damage. Indirect effects by this trait was found to be positively low through adult midges per earhead, eggs per hundred florets, earhead weight and grain yield per plant. Negative indirect effect was low through glume length - g_1 and effects were very negligible through all other parameters.

4.10.8 Adult emergence per earhead

Although it had an positively moderate total correlation, it made very low direct contribution in negative direction on per cent grain damage. However, it indicated

positively low indirect contribution through larvae per hundred florets.

Its indirect contribution via, all other characters found to be very negligible either positively or negatively.

4.10.9 Earhead weight per plant

Negatively low direct effect was exhibited by this parameter on per cent grain damage and so was the case with indirect effects through glume length - g_2 , eggs per hundred florets and moderate through larvae per hundred florets. Low positive indirect contribution was noticed through anther colour, glume length - g_1 , and hundred grain weight. It exhibited negligible indirect effects in negative direction via all other characters.

4.10.10 Grain yield per plant

On per cent grain damage, it had low negative direct effect and negatively low indirect contribution through glume length - g_2 , eggs per hundred florets, and moderately through larvae per hundred florets. While its indirect contribution through all other traits was found to be negligible either negatively or positively.

4.10.11 Hundred grain weight

Its direct contribution was positively very negligible and indirectly low contribution was found in positive manner through glume length - g_1 . It had negligible indirect effects either positively or negatively through all other characters.

4.11 TAM 2566 x SPV 829

The results of Direct and indirect effects of different characters on per cent grain damage studied in F_3 population of the cross TAM2566 x SPV 829 and the results are presented in table 12.

4.11.1 Days to fifty per cent flowering

The direct effect of this trait on percentage grain damage was negatively low. Its negative indirect effects were also noticed through number of adult midges per earhead, glume length - g_2 , and larvae per hundred florets. Positively very low indirect contribution of this character was noticed through anther colour, glume length - g_1 , eggs per hundred florets, adult emergence, earhead weight, grain yield weight and hundred grain weight.

4.11.2 Anther colour

As indicated in the table, anther colour exhibited very low positive direct effect on chaffiness. Its indirect

Table 12. Direct and indirect effects of different characters on percentage damage by *C. sorghicola* (Coq.) in a cross TAM2566 x SPV 829

Plant and insect parameters	Day to 50% flowering	Anther colour	No. of midges/earhead	G1	G2	Eggs/100 florets	larvae/100 florets	Earhead midge emergence	Earhead weight	Grain yield weight	100 grain weight	Percentage of damage (dependent)
Days to 50% Flowering	-0.1418	0.0279	-0.0374	0.0008	-0.0011	0.0134	-0.1183	0.0035	0.0140	0.0019	0.0047	-0.2323
Anther colour	-0.0479	0.0826	0.0003	-0.0001	-0.0012	0.0009	0.0450	0.0137	-0.0118	-0.0018	0.0094	0.0892
No. of midges/earhead	-0.0343	-0.0002	-0.1549	-0.0010	0.0079	-0.0215	0.2721	0.0321	-0.0322	-0.0043	0.0455	0.1093
G1	-0.0083	-0.0006	0.0110	0.0145	-0.0693	0.0052	-0.0333	0.0032	-0.0107	-0.0029	0.0176	0.0736
G2	-0.0022	0.0014	0.0173	0.0142	-0.0709	-0.0039	0.0514	0.0108	-0.0131	-0.0032	0.0059	0.0075
Eggs/100 florets	0.0228	-0.0009	-0.0398	-0.0009	-0.0033	-0.0838	0.9483	0.0861	-0.0803	-0.0099	0.0139	0.8522
Larvae/100 florets	0.0169	0.0037	-0.0425	-0.0005	-0.0037	-0.0801	0.9913	0.0863	-0.0897	-0.0112	0.0164	0.8871
Earhead midge emergence	-0.0041	0.0094	-0.0412	0.0004	-0.0063	-0.0598	0.7093	0.1206	-0.0658	-0.0072	-0.0132	0.6420
Earhead weight	-0.0158	-0.0077	0.0396	-0.0012	0.0074	0.0535	-0.7076	-0.0632	0.1256	0.0153	-0.0399	-0.5939
Grain yield weight	-0.0170	-0.0091	0.0413	-0.0026	0.0143	0.0515	-0.6883	-0.0543	0.1197	0.0161	-0.0363	-0.5648
100 grain weight	0.0035	-0.0041	0.0375	-0.0014	0.0022	0.0062	-0.0867	0.0085	0.0267	0.0031	-0.1878	-0.1924

contribution through many traits such as number of adult midges per earhead, eggs per hundred florets, larvae per hundred florets, adult emergence per earhead, and hundred grain weight was found to be positively low. Indirect very low negative effects were noticed via, days to 50 per cent flowering, glume length - g_1 , glume length - g_2 , earhead midge emergence and hundred grain weight.

4.11.3 Number of adult midges per earhead

The direct contribution of this character was negatively low on per cent grain damage. It showed moderately positive indirect effect through larvae per hundred florets, but negligible positively indirect effects were found through glume length - g_2 , adult emergence per earhead and hundred grain weight. On the other hand, it exhibited very low negative indirect effects through days to fifty per cent flowering, anther colour, glume length - g_1 , eggs per hundred florets, earhead midge emergence and grain yield per plant.

4.11.4 Glume length - G_1

The glume length showed positively very low direct effect on per cent grain damage. It also revealed that indirect contribution of this parameter either positively or negatively was negligible through many traits viz; days to

fifty per cent flowering, anther colour, number of adult midges per earhead, glume length - g_2 , eggs per hundred florets, larvae per hundred florets, adult emergence per earhead, earhead weight, grain yield per plant and hundred grain weight.

4.11.5 Glume length - G_2

This character showed negatively very low direct effects on per cent grain damage. Its indirect contribution either positively or negatively was very low through all other traits.

4.11.6 Eggs per hundred florets

Although its total correlation was found to be highly positive, it exhibited negatively very low direct effect on per cent grain damage. However, its indirect contribution through larvae per hundred florets was found to be highly positive. This character showed negligible positive indirect effects through days to fifty per cent flowering, adult emergence per earhead, hundred grain weight and negative indirect contribution through anther colour, number of adult midges per earhead, g_1 , g_2 earhead weight and grain yield per plant.

4.11.7 Larvae per hundred florets

It is this parameter which indicated highly positive direct effect on per cent grain damage. Positively very low indirect effects were found through days to fifty per cent flowering, anther colour, adult emergence per earhead and hundred grain weight. It showed negatively negligible indirect effects through number of adult midges per earhead, glume length - g_1 , glume length g_2 , eggs per hundred florets, earhead midge emergence and grain yield per plant.

4.11.8 Adult emergence per earhead

Though this trait had an positively high total correlation but exhibited positively low direct effect on per cent grain damage. In contrast, this character showed positively high indirect effect through larvae per hundred florets. While indirect contribution through anther colour and glume length - g_1 were found to be positively very low. Negatively negligible effects were noticed through days to fifty per cent flowering, number of adult midges per earhead, glume length - g_2 , eggs per hundred florets, earhead midge emergence, grain yield per plant and hundred grain weight.

4.11.9 Earhead weight per plant

The direct contribution of this trait on per cent grain damage was positively low. It exhibited positively

negligible indirect effects through number of adult midges per earhead, glume length g_2 , eggs per hundred florets and grain yield per plant. It also showed negative indirect effects through days to fifty per cent flowering, anther colour, glume length - g_1 , hundred grain weight and larvae per hundred florets, but through last character it had high negative effect.

4.11.10 Grain yield per plant

This parameter contributed very low direct effect on per cent grain damage. Its indirect contribution through adult emergence was found to be positively low and negatively very high through larvae per hundred florets. While its indirect contribution through other characters either positively or negatively was found to be very negligible.

4.11.11 Hundred grain weight

It had an negatively low direct effect on chaffiness. Through all the characters it showed very negligible indirect contribution either positively or negatively.

CHAPTER - V

DISCUSSION

V. DISCUSSION

Sorghum is an important food crop in African and Asian countries. Although, high yielding varieties and hybrids were developed during seventies and eighties, the desired increase in production could not be achieved because of their susceptibility to insect pests and diseases. The sorghum earhead midge *Contarinia sorghicola* (Coq.) continues to hold a key pest position limiting the production of sorghum in India and other countries of the world. The losses in Tropical Asia and Africa may exceed 50 per cent and complete loss of crops in Australia and Argentina (Singh, 1987). Even in India, States like Maharashtra, Karnataka, Tamil Nadu and Haryana suffer great loss in Sorghum production due to midge attack especially in endemic areas.

In the transitional belt of Karnataka, the farmers of Dharwad, Haveri, Ranebennur and Bailhongal face midge problem every year. Keeping in view the many disadvantages of repeated application of pesticides and non-availability of biocontrol agents in adequate numbers, it was felt that the development of resistant hybrids and varieties would be a long lasting solution for this menace.

The present study forms a continuity of the investigations aimed at developing midge resistant types (strains or crosses). In an earlier study, involving a 8 x 8 set of diallel crosses, Prabhu (1989), a Post-graduate student of the Department of Entomology, UAS, Dharwad had worked out the genetics of resistance. From the material, twenty five F_2 crosses which showed resistance to midge were selected. But only three crosses viz., DJ6514 x SPV829, TAM2566 x SPV813 and TAM2566 x SPV829, that were found to be outstanding with respect to resistance and yield characters, were advanced to further generation. This material was handled by the author for detailed study to understand the nature of variability for midge resistant parameters and association pattern among traits related to midge resistance in each of these crosses. Besides, it was also aimed to select superior midge resistant segregants in these crosses for use in further breeding programme.

The results obtained from the study are discussed under the following heads and sub heads.

5.1 Interplant variability among parents

It was found that interplant variability in the parents was less compared to F_3 generations for all the

characters. This is expected since parents are true breeding lines compared to the F_3 population which are segregating.

Early blooming helps the crop to escape the midge attack. Conversely, late flowering is prone to attack. It was noticed that among the parents, SPV829 flowered earliest with a mean of 66.5 days which showed a range of 64-69 days. Coefficient of variability was high for this parent compared to other parents. Although other two parents viz., TAM2566 and DJ6514 showed similar high mean (74.10) values, but they exhibited least coefficient of variabilities of 1.04 and 1.26 per cent, respectively. Hence with respect to trait, as these two parents indicated least coefficient of variabilities, it is possible to obtain desirable population in succeeding generations utilising these parents in resistant crosses.

The anther colour of the particular genotype plays an important role for the attraction of midges and indirectly influence the resistance of that genotype. According to Danapur (1984), lighter yellow colour of the anthers attracted more number of midges compared to darker yellow colour.

The highest mean (3.80) for this trait was indicated by the parent TAM2566 followed by the parent SPV829. Latter

parent also showed high variance with coefficient of variability value of 19.15 percentage. Least variance (0.16) was exhibited by both TAM2566 and DJ6514 parents, while least coefficient of variability (10.53) was indicated by TAM2566 followed by DJ6514 (18.18%). Therefore, as TAM2566 was found to be more stable, it should be possible to obtain good segregants showing desirable character in succeeding generation utilising this parent in a cross.

Sharma (1990) reported that a genotype maybe more attractive to adult midges but showed antixenosis to oviposition. Similar findings were also obtained in the present investigation. The parent TAM2566 showed lowest mean number of adult midges per earhead (6.15) with its least range of 3-8 followed by DJ6514 which recorded mean of 6.55. Coefficient of variability was least in DJ6514 (25.76%) followed by TAM2566 (25.85%) compared to other two parents. Since DJ6514 and TAM2566 were found to be more stable, hence desired population can be obtained in succeeding generation of utilising these two parents in crosses.

The short glume is considered as an important morphological factor contributing to the midge resistance (Ball and Hastings, 1912, Jadhav and Jadhav, 1978 and Singh

1987). In the present study, TAM2566 showed smallest glume length (G_1) with a mean of 2.96 mm and a variance of 0.006 with coefficient of variability of 2.79 per cent. DJ6574 and TAM2566 had the smallest glume length (G_2). Variances of 0.004 and 0.005 with coefficient of variability of 2.08 and 2.24 per cent were recorded for both the parents, respectively.

Among the parents least mean number of eggs (12.25) was noticed in the parent TAM2566 which showed coefficient of variability of 31.71 per cent. The present findings are in conformation with the results obtained by Rossetto *et al.* (1984) who indicated that non preference to oviposition is the or one of the mechanisms of resistance. According to Waquil *et al.* (1986), susceptible strains were infested with four to five times more number of eggs as compared to resistant ones.

The lower larval count is considered as one of the important parameters contributing to the resistance. Even there may be more number of eggs initially and later less number of larvae can be seen in resistant genotypes (Sharma, 1983, 1985 and Sharma *et al.*, 1990). In the present study also the resistant parent DJ6514 recorded the lowest (8.15) number of larvae per hundred florets followed by TAM2566 (13.00).

Both showed coefficient of variability of 19.12 and 23.08 per cent, respectively.

The resistant genotypes DJ6514 and TAM2566 recorded lowest mean percentage of grain damage and the values were 14.73 and 18.58, respectively. The present findings are in conformaty with the results of Bhuti and Kulkarni, 1982; Mote, 1982; Hagio *et al.*, 1985; Natarajan and Chellaiah, 1986; Sharma *et al.*, 1988 and 1989. TAM2566 showed coefficient of variability of 17.57 per cent followed by DJ6514 (12.48%).

Number of adults emerged per earhead considered to be one of the most reliable parameters to assess the level of midge resistance. The resistant genotypes recorded lesser number of adult emergence as compared to that of susceptible (Lara *et al.*, 1977). The least mean number of midges (14.75) emerged in DJ6514 followed by TAM2566 (19.60%).

The primary objective of the present study is not only to find out the best resistant parent but also to ascertain the genotype possessing good agronomic characters for higher yields. The earhead weight is one of the important parameters contributing for higher yields. In the present investigation, TAM2566 showed the highest earhead weight

(89.17g) g followed by DJ6514 (55.48g) with low coefficient variability of 5.16 and 7.68 per cent, respectively.

In the present study, the highest grain yield was recorded in TAM2566 with a mean of 49.60 g/plant with least variance and coefficient of variability, while the genotype SPV829 indicated moderate grain yield per plant (27.58g).

Hundred grain weight is again an important yield component which contribute to grain yield. In the parental material, it was noticed that TAM2566 recorded the highest hundred grain weight (2.65g) and the other parents recorded more or less similar mean values.

5.2 Interplant variability among crosses in F_3 generation

Among the three crosses, TAM2566 x SPV829 flowered earliest with a mean of 70.00 days to 50 per cent flowering with the highest coefficient of variability (5.64%). The other two crosses viz., TAM2566 X SPV813 and DJ6514 x SPV 829 with the mean values of 71.13 and 71.43 days exhibited low coefficient variability values of 5.31 and 5.59, respectively. Hence, as a result of high coefficient of variability noticed in TAM2566 x SPV829 better selection can be obtained with respect to this trait in segregating population.

Anther colour

In F_3 generation DJ6514 x SPV829 showed the widest range (1-4) for anther colour grades with a mean of 2.35 and variance of 1.09 exhibiting very high coefficient variability of 44.51 per centage, followed by TAM2566 x SPV829 which showed range of 1-4 and mean of 3.63 with a high variance (1.68) and high coefficient of variability (35.70%). Since both the crosses exhibited high variances and coefficient variability critical selection pressure could be exerted in these segregating populations.

Number of adult midges per earhead

In the present study, although these crosses did not indicate much variation in this trait, the least mean (6.80) and widest range (2-25) was recorded in TAM2566 x SPV813 followed by TAM2566 x SPV829. Obviously both the crosses showed high coefficients of variability and high variances. Since the number of adult midges indicates an important resistant trait, selection for segregants showing least no of adult midges can be made in the populations of both these crosses.

Glume length - G_1 (mm)

In F_3 generation, least mean glume length- g_1 was noticed in TAM2566 x SPV813 (2.99mm) with a CV vaue of 7.04%

followed by TAM2566 x SPV 829 (3.34mm) with a CV value of 6.68 per cent. According to Sharma *et al.* (1990), shorter the glume length more would be the resistance. Since these two crosses exhibited high coefficient of variability indicating low mean glume length, there is scope to select segregants with low glume length in these two populations.

Glume length- G_2 (mm)

Among three crosses, TAM2566 x SPV813 showed least mean values (3.04mm) followed by TAM 2566 x SPV 829 (3.32mm). As both the crosses showed very high coefficient of variability, selection in these segregating populations is expected to be useful.

Eggs per hundred florets

In F_3 generation, least mean number of eggs (27.16) was recorded in TAM2566 x SPV829 with a wide range of 5-79 eggs followed by TAM2566 x SPV813 with mean and range being 33.45 and 7-99, respectively. Both the crosses exhibited high variances of 212.46 and 277.31, respectively, with high coefficients of variability. It may be pointed out here that one of the parents of both the crosses i.e, TAM2566 had less mean number of eggs. Non preference of the genotype for oviposition is the mechanism of resistance, according to

Rossetto (1977) and Sharma *et al.* (1990). In this study, since both the crosses expressed high variability values, there is a distinct possibility of making better selection for segregants showing less number of eggs in these segregating populations.

Larvae per hundred florets

The least mean number of larvae per hundred florets (24.15) was noticed in TAM2566 x SPV813 with its range of 2-64, followed by TAM2566 x SPV829. Both the crosses showed high variances and high percentage coefficient of variability and therefore, desirable selection could be made in these population.

Per cent grain damage

For determining the midge resistant level, this is one of the most reliable parameters. Initially there may be more number of larvae, but survivability of the larvae may be less indicating mortality during development and thus antibiosis reported to be the mechanism of resistance (Sharma, 1985b).

In the present study, although more or less similar mean percentage of damage was exhibited by all the three crosses, high variances of 42.45 and 42.24 with a high

coefficient variabilities of 23.98 and 22.83 per cent were noticed in crosses TAM2566 x SPV813 and DJ6514 x SPV829, respectively. These two crosses indicated the possibility of selecting segregants with less damage.

Adult emergence per earhead

Among the three crosses, least mean number of adults emergence (30.67) noticed in TAM2566 x SPV813 followed by DJ6514 X SPV829 (31.03) with the CV values of 33.63 and 29.28 per cent, respectively.

Earhead weight per plant (g)

Among the three F_3 population, TAM2566 x SPV829 recorded the highest mean (45.56), wider range (28-79.20) and high variance (150.30) with coefficient variability of 26.85per cent. Ultimate objective of the crop improvement programme is to ascertain best crosses exhibiting good agronomic characters besides resistance to midge. From this point, as TAM2566 x SPV829 and TAM2566 x SPV813 showed high variabilities, it is possible to make considerable improvement for grain weight/yield through selection in these segregating populations.

Grain yield per plant (g)

The highest grain yield per plant was recorded in TAM2566 x SPV829 (31.40), with wider range 10.75 - 68.50.

Other two crosses viz., TAM2566 x SPV813 and DJ6514 X SPV 829 recorded 23.52 and 28.55 respectively. High variance of 143.61 and coefficient variability of 38.16 per cent exhibited by TAM2566 x SPV829 was followed by DJ6514 x SPV829 which recorded the CV of 30.31 per cent and variance of 31.63. As these two crosses showed high CV values, it should be provide good opportunity to obtain good segregants with respect to this character by making selection.

Hundred grain weight (g)

Among the three crosses, TAM2566 x SPV829 showed highest mean weight of 2.50 g followed by TAM2566 x SPV813 (2.09). While highest coefficient variability values of 11.46 and 11.23 per cent were noticed incrosses viz., TAM2566 x SPV813 and DJ6514 x SPV829 respectively. As a result of their high variability values, considerable improvement can be made by selection in these two crosses.

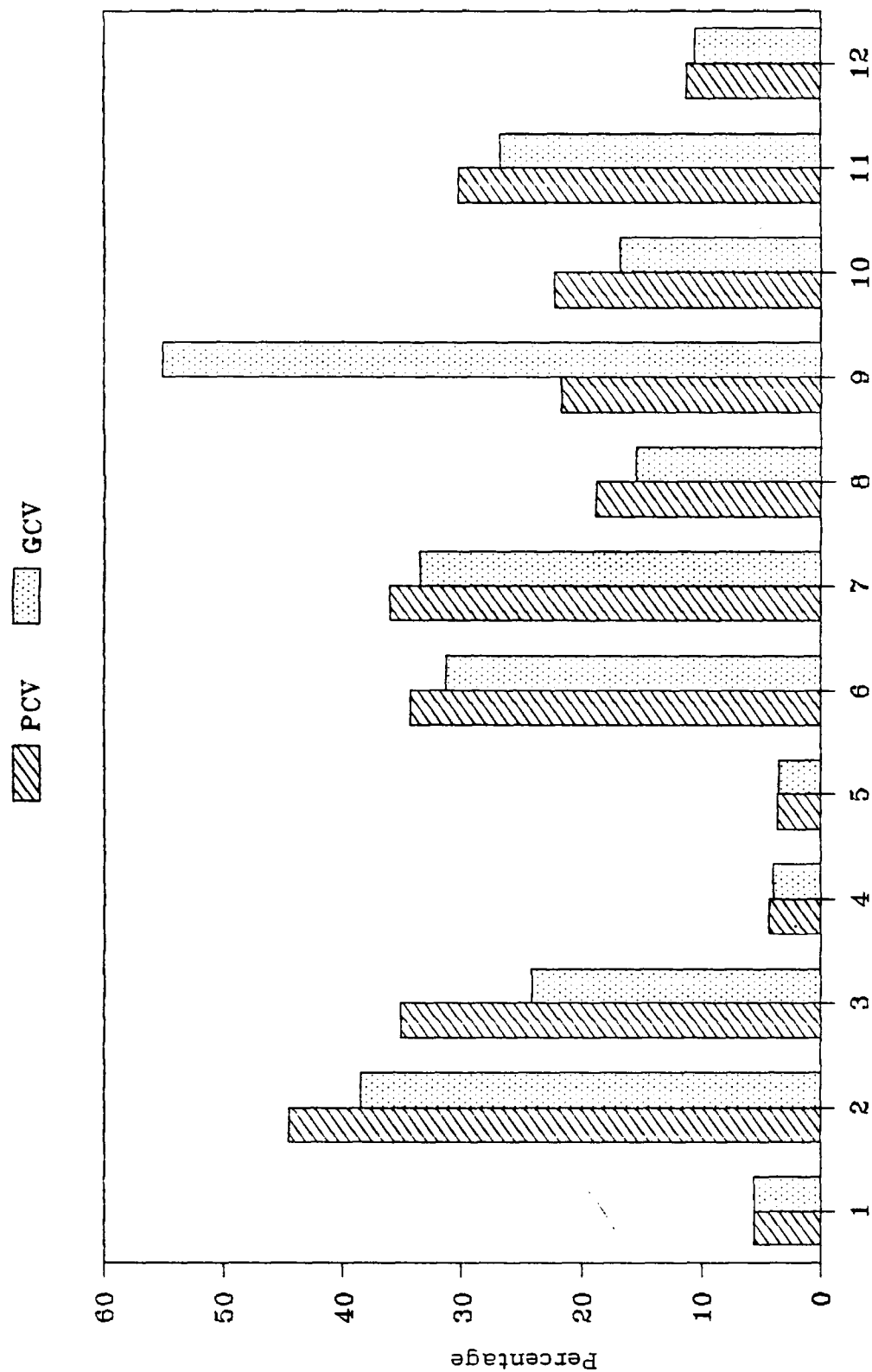
Interplant variability studies carried out in respect of twelve characters among the three crosses revealed that the cross TAM2566 x SPV829 flowered earliest with a mean of 70.00 days exhibiting high variability. For anther colour, least mean (2.35) was noticed in DJ6514 x SPV829 with high degree of variability. The least mean number of adult midges

(8.15) was noticed in DJ6514 x SPV829 followed by TAM2566 x SPV829 with variability values of 35.19 and 51.94 per cent respectively. Highest coefficient of variability (7.04 %) was recorded in TAM2566 x SPV813 with a smaller mean glume length - g_1 (2.99 mm). TAM2566 x SPV829 had the least mean glume length g_2 (3.32 mm) with high variability. Least mean number of eggs (27.16) was recorded in TAM2566 x SPV829 with high variability (53.67). TAM2566 x SPV829 showed least mean number of larvae (24.15) with variability of (46.63). Least mean number of adults emerged in TAM2566 x SPV813 indicating variability (33.63%). Grain damage was least in TAM2566 x SPV813 exhibiting high variability (23.98%).

Variability per centage for TAM2566 x SPV829 was 26.85, which recorded high earhead weight (45.66 g) and high grain yield (31.40 g) and high CV (38.16%). Highest hundred grain weight (2.5g) noticed in TAM2566 x SPV829 with a high CV (9.33%).

5.3 Phenotypic and genotypic coefficient of variability heritability and genetic advance in a cross DJ6514 x SPV829

In a sound breeding programme, one should assess the genotypic (GCV) and phenotypic (PCV) of the material under



Parameters
 Fig. 1. Phenotypic and genotypic coefficient of variability in respect of different characters in DJ6514 x SPV829

1-50% flowering; 2-Anther colour; 3-No. of midges; 4-G1; 5-G2; 6-Eggs/100 florets; 7-Larve/100 florets; 8-% grain damage; 9-Adult emergence; 10-Earhead weight; 11-Grain yield/plant; 12-100 grain weight

study. Higher the genotypic component in the variability, greater will be the effectiveness of selection made and if environmental component is more, selection will be ineffective. Therefore, to compare the phenotypic and genotypic variation present for the characters, the phenotypic and genotypic coefficients of variability were computed. In the literature reports pertaining to genetic information on resistant traits viz., eggs per hundred florets, larvae per hundred florets, adult emergence and per cent grain damage were not seen.

It was observed that phenotypic coefficient of variation was very high for all the characters than GCV. The phenotypic and genotypic coefficient of values were found to be very high for anther colour, number of adult midges per earhead, glume length g_1 and g_2 number of eggs per hundred florets, number of larvae per hundred florets and grain yield per plant. Sindagi *et al* (1970b), Gopal Krishna Bhat (1974), Abul-el-gasim and Kambal (1979) and Kumar and Singh (1986) recorded highest PCV and GCV for grain yield per plant. The results obtained indicate that high diversity of the parents for these characteristics could be the reason for getting high variation. It is clearly revealed that there is ample scope for selection in this cross for increased

expression of these characters, since environmental influence on them is narrow. Moderate values of gcv and pcv were noticed for the adult emergence per earhead, percentage grain damage and earhead weight per plant. But the difference between PV and GV was slightly more indicating the larger influence of environmental factors on these parameters. While 100 grain weight and days to fifty percent flowering showed moderate to low PCV and GCV values. The narrow difference between PV and Gv values in 100 grain weight and days to fifty per cent flowering indicate the lower influence of environment and reflect on the reliability of selection based on phenotypic performance. Sindagi et al. (1970b) found least variability between PCV and GCV for flowering date. Gopal Krishna Bhat (1974) observed similar variation between PCV and GCV for the hundred grain weight.

The coefficient of variation indicates only the extent of variability existing for various characters, but does not give an idea about heritable portion of it. Therefore, it is essential to know the heritability which permits the greater effectiveness of selection by separating the environmental influence from the total variability and to indicate the accuracy with which a genotype can be identified by its phenotypic performance. As such heritability in broad

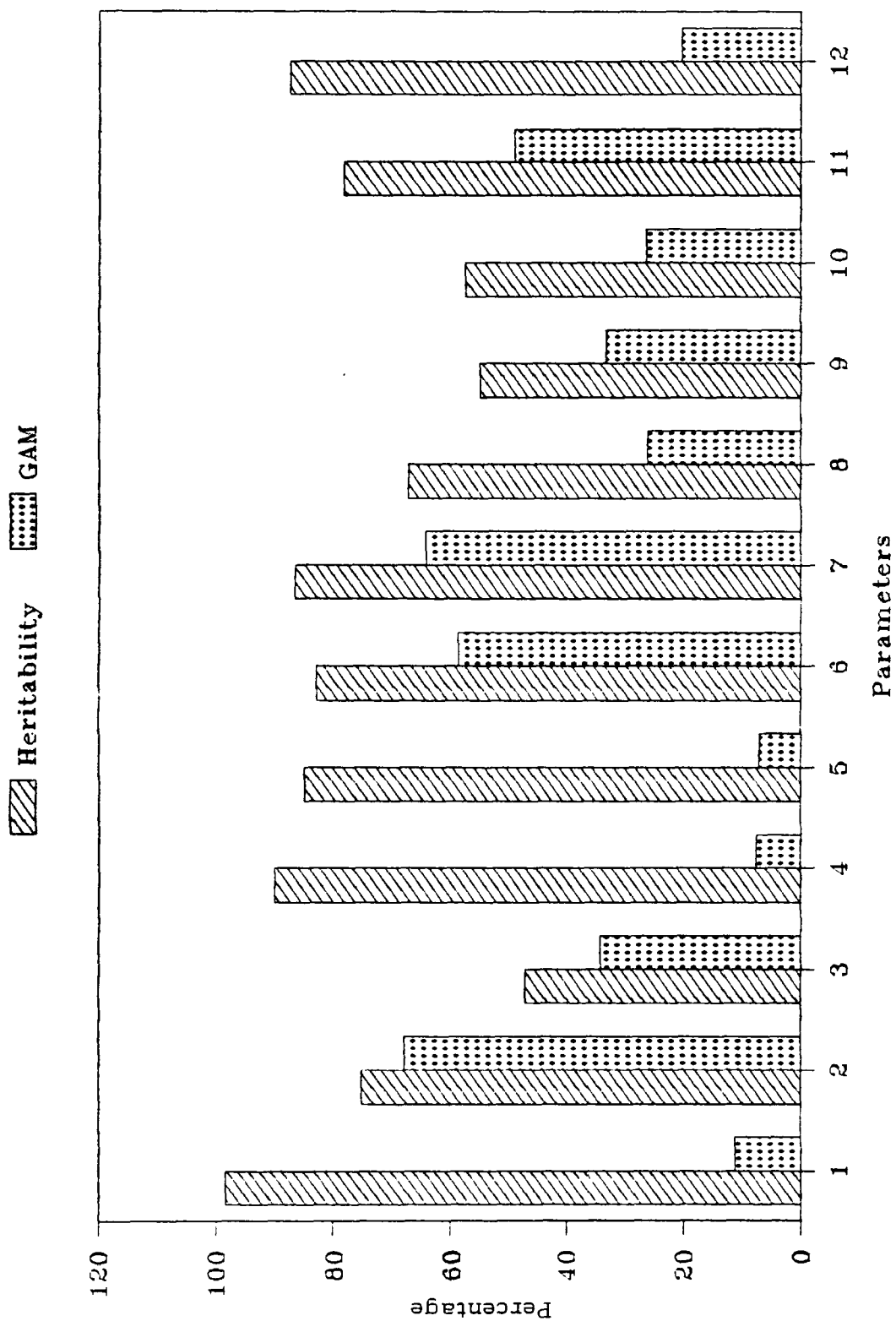


Fig. 2. Heritability and GAM in respect of different characters in DJ6514 x SPV829

1-50% flowering; 2-Anther colour; 3-No. of midges; 4-G1; 5-G2;
 6-Eggs/100 florets; 7-Larve/100 florets; 8-% grain damage; 9-Adult emergence;
 10-Earhead weight; 11-Grain yield/plant; 12-100 grain weight

sense is the proportion of genotypic variability to the total variability.

Highest heritability estimates were obtained for the characters viz; days to 50 per cent flowering, glume length $-g_1$, g_2 , numbers of eggs per hundred florets, number of larvae per hundred florets and hundred grain weight. High heritability values were obtained for days to fifty per cent flowering in F_3 generation by But Liang (1967), Liang and Walter (1967), Alikhan and Weibel (1969), Liang *et al.* (1969a), Chung and Liang (1970), Naphade (1973), Dimmar (1978), Nagabasiah *et al.* (1981) and Kukadia *et al.* (1983a). Estimates of high heritability values for 100 grain weight were also obtained by Mamdouh *et al.* (1971), Singh (1972), Napade (1971), Govil (1979), Panchal (1979), Patel (1980) and Kumar and Singh (1986). The high heritability values for above parameters indicate negligible influence of environmental factors and endorse that these traits can be considered for improvement by selection.

Moderately high values of heritability recorded for anther colour, adult emergence and grain yield per plant. While moderately low heritability noticed for per cent grain damage and earhead weight per plant suggest lower efficacy of

selection for these two characters. Least heritability was noticed for number of adult midges per earhead.

Heritability estimates in broad sense are not the true indicators of the genetic potentiality of the genotypes. Hence, if heritability values are considered in conjunction with the predicted genetic gain the reliability of the parameter as a tool in selection programme will increase.

In the present study glume length- g_1 , glume length- g_2 , number of eggs per hundred florets, and larva per hundred florets showed high heritability values coupled with high genetic advance. This indicates that these characters may be governed by additive gene action which is desirable for selecting true breeding types in segregating population.

High heritability with low genetic advance noticed in days to fifty per cent blooming and hundred grain weight suggests that these characters are probably governed by non-additive and/or environmental factors. Moderately high heritability coupled with the moderate genetic advance was recorded for adult emergence and grain yield per plant. This suggests moderate expected response to selection, proportionate to the additive component of gene action. Moderately high heritability coupled with low genetic advance

noticed for per centage grain damage and anther colour, indicates that this parameter is governed by non-additive gene action. Therefore, in order to select good resistant types in this F_3 population, it is suggested to make a selection for number of eggs, larvae per hundred florets rather than directly for percentage of damage.

Low heritability coupled with moderate genetic advance recorded for earhead weight per plant offers a moderate response to selection.

Low heritability coupled with low genetic advance noticed in number of adult midges per earhead indicates lower proportion of genotypic component in the total variability. Therefore, selection based on this character may not be effective.

Among all parameters studied in DJ6514 x SPV829 cross anther colour, glume length, g_1 , g_2 , number of eggs per hundred florets and number of larvae per hundred florets showed high genotypic coefficient of variation, high heritability accompanied by high magnitude of genetic advance over mean. Therefore it should be possible to exercise more intensive selection in this F_3 population to achieve considerable gain in identifying resistant types.

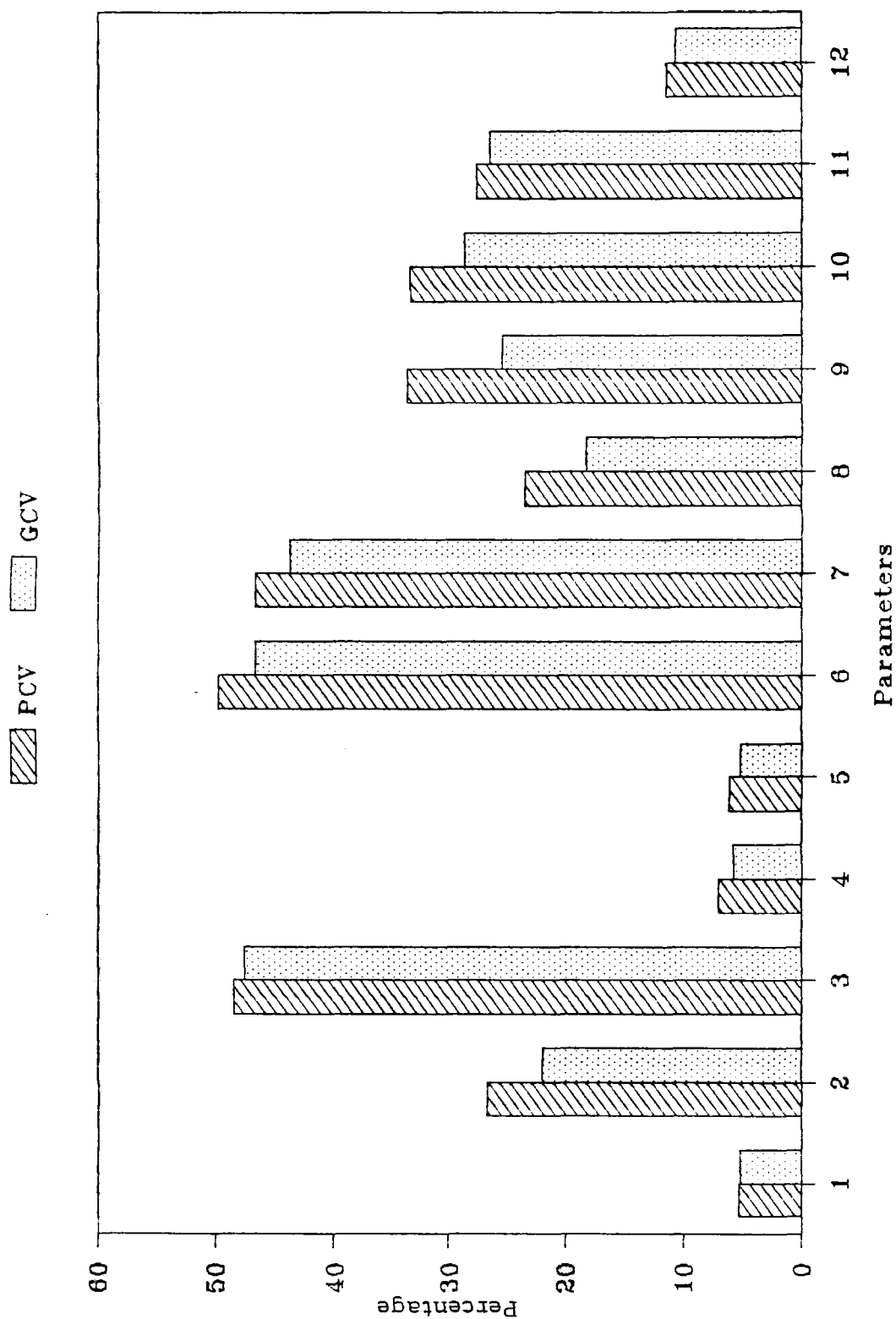


Fig. 3. Phenotypic and genotypic coefficient of variability in respect of different characters in TAM2566 x SPV813

1-50% flowering; 2-Anther colour; 3-No. of midges; 4-G1; 5-G2;
 6-Eggs/100 florets; 7-Larve/100 florets; 8-% grain damage; 9-Adult emergence;
 10-Earhead weight; 11-Grain yield/plant; 12-100 grain weight

5.3.1 Phenotypic and genotypic coefficient of variability, heritability and genetic advance in a cross TAM2566 x SPV813

In this cross it was noticed phenotypic coefficient of variation was high for all the characters compared to GCV. Among all the characters GCV and PCV were found to be high for number of adult midges per earhead, number of eggs per hundred florets and number of larvae per hundred florets. Obviously the results obtained suggests that considerable ammount of variability existed because of high diversity of parents for these parameters. Hence ideal selection can be obtained in segregating population since the environmental influence on them is narrow.

Phenotypic and genotypic coefficient of variation were found to be moderate for anther colour, percentage grain damage, adult emergence per earhead and earhead weight and considerable difference between PV and GV values indicates larger influence of environmental factors on those parameters. Although grain yield per plant exhibited moderate values of PCV and GCV but the difference between PV and GV was narrow. Similar trend was also noticed in days to 50 per cent flowering and hundred grain weight, which indicates less

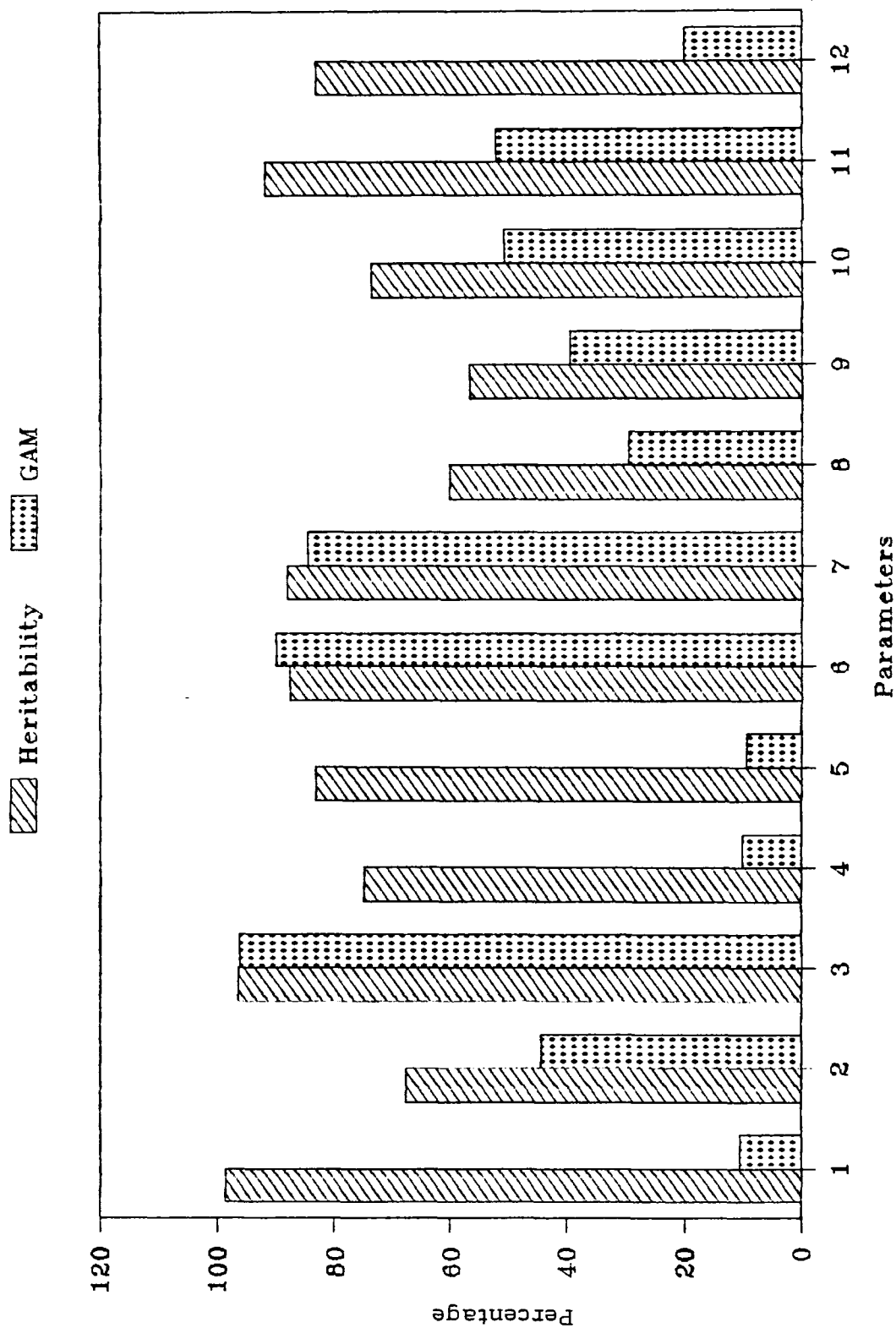


Fig. 4. Heritability and GAM in respect of different characters in TAM2566 x SPV813

1-50% flowering; 2-Anther colour; 3-No. of midges; 4-G1; 5-G2;
 6-Eggs/100 florets; 7-Larve/100 florets; 8-% grain damage; 9-Adult emergence;
 10-Earhead weight; 11-Grain yield/plant; 12-100 grain weight

environmental influence and is desirable to make a selection based on phenotypic performance.

Broad sense heritability recorded to be high in days to 50 per cent flowering, number of adult midges per earhead, glume length $-g_2$, number of eggs per hundred florets, number of larvae per hundred florets, grain yield per plant and hundred grain weight. The results indicate that low influence of environmental factors on these parameters and can be considered for improvement by selection in segregating population.

The parameters such as anther colour, glume length $-g_1$, percentage grain damage, adult emergence and earhead weight per plant showed moderately high heritability which indicates lower efficacy of selection in segregating population of succeeding generation.

Estimates of heritability are not the true indicators of the genetic potentiality of the genotypes. According to Johnson *et al.* (1955), the heritability estimates when used in conjunction with the genetic advance provides a better information than heritability alone.

High heritability coupled with high genetic advance noticed in glume length g_2 , eggs per hundred florets, larvae

The results obtained in a cross TAM2566 x SPV813 revealed that number of adult midges per earhead, g_2 , number of eggs per hundred florets, number of larvae per hundred florets and grain yield per plant showed high magnitude of genetic advance expressed as a percentage of mean accompanied by high heritability values indicating that selection in this F_3 population is effective to achieve considerable gain in identifying resistant types.

5.3.2 Phenotypic and genotypic coefficient of variation, heritability and genetic advance in a cross TAM2566 x SPV829

Phenotypic coefficient of variation in all the parameters was high than GCV. Higher values of GCV and PCV were noticed for number of adult midges per earhead, number of eggs per hundred florets and number of larvae per hundred florets. These results strongly indicate that high diversity of the parents for these parameters could be the reason for getting higher variation. Hence, ideal selection can be obtained in segregating population as environmental influence on them is narrow.

Although anther colour, percentage grain damage and adult emergence per earhead showed moderately high GCV and PCV

per hundred florets and grain yield per plant. The results obtained indicate the contribution of additive gene for these characters. This would help in rapid improvement of these characters and also for predicting the extent of improvement that can be achieved by selection in segregating population.

High heritability coupled with moderately low genetic advance was noticed in days to 50 per cent flowering, number of adult midges per earhead and hundred grain weight reveals that these characters are probably governed by non-additive or the influence of environmental factors.

Earhead weight per plant and adult emergence per earhead showed moderately high heritability with genetic advance which suggests moderate response to selection as it indicates additive component of gene action.

Anther colour and percentage grain damage exhibited moderately low genetic advance with moderately low heritability which indicates non-additive gene action for these characters. Hence, to obtain ideal population in segregating generation, it is advisable to make selection on resistant parameters rather than making a selection directly on per cent grain damage.

values; but the difference in PV and GV was more indicating influence of environmental factors on these parameters.

The narrow differences existed between PV and GV values for the characters viz; days to fifty per cent flowering, earhead weight, grain yield per plant and hundred grain weight reflected the low influence of environmental factors on these parameters. Therefore, ideal selection can be made for increased values of these characters in segregating population based on phenotypic performance.

In this cross among all the parameters, days to 50 per cent flowering, glume length g_1 and g_2 , number of eggs per hundred florets, number of larvae per hundred florets, earhead weight and grain yield per plant showed very high heritability estimates indicating that selection of superior segregants on the basis of phenotype will be more efficient for these characters as environmental influence on them is negligible.

Moderately high heritability values noticed in anther colour, number of adult midges per earhead and hundred grain weight suggests less efficacy of selection in these parameters.

Grain damage recorded moderately low heritability indicates selection is ineffective.

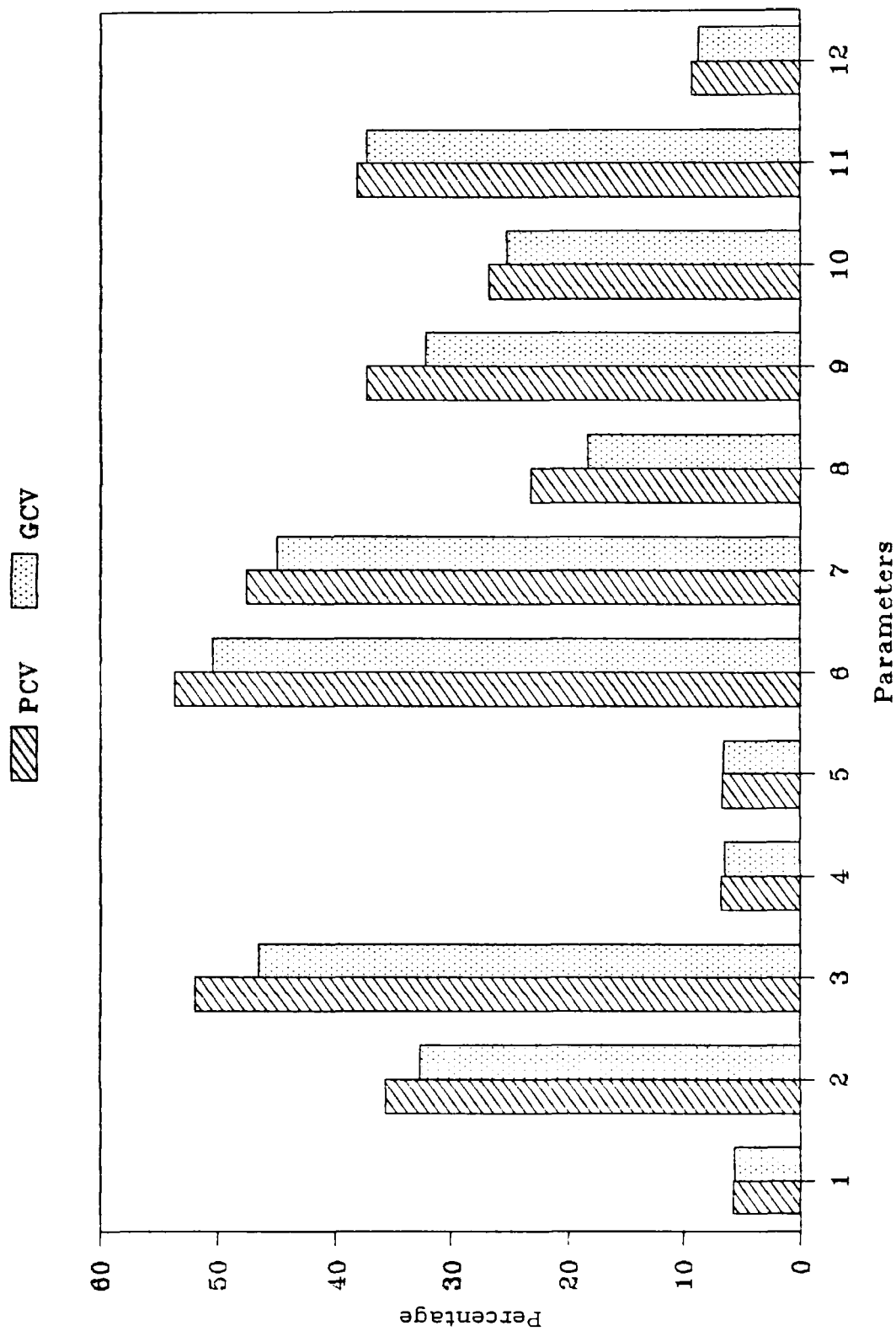


Fig. 5. Phenotypic and genotypic coefficient of variability in respect of different characters in TAM2566 x SPV829

1-50% flowering; 2-Anther colour; 3-No. of midges; 4-G1; 5-G2;
 6-Eggs/100 florets; 7-Larve/100 florets; 8-% grain damage; 9-Adult emergence;
 10-Earhead weight; 11-Grain yield/plant; 12-100 grain weight

The traits such as glume length- g_1 , g_2 , number of eggs per hundred florets, number of larvae per hundred florets, earhead weight per plant and grain yield per plant showed high heritability coupled with high genetic advance. These results revealed the contribution of additive gene action. Therefore, ideal selection can be made for true breeding types in segregating population for these characters.

High heritability values coupled low genetic advance noticed in days to 50 per cent flowering, anther colour, number of adult midges per earhead and hundred grain weight suggest that these parameters are governed by non-additive gene action or influence of environmental factors.

Moderately low heritability in respect of per cent grain damage with low genetic advance indicates non-additive gene action on this trait. Therefore, selection for superior types in the F_3 population should be carried out in segregating population on other resistant parameters rather than directly for per cent grain damage.

Among all the parameters in the cross TAM2566 x SPV829 glume length g_1 , g_2 number of eggs per hundred florets, number of larvae per hundred florets, earhead weight per plant and grain yield per plant exhibited high GCV, high

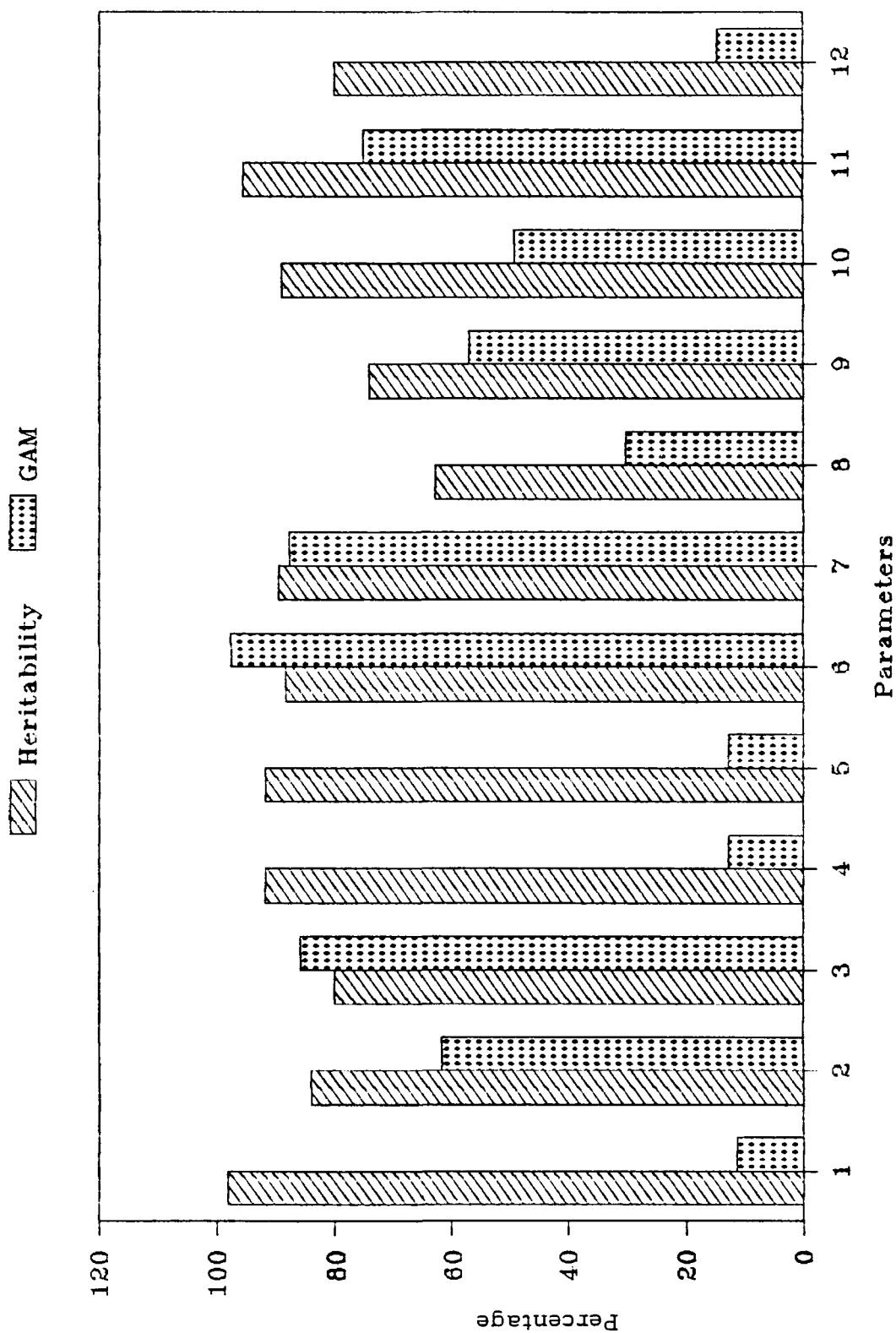


Fig. 6. Heritability and GAM in respect of different characters in TAM2566 x SPV829

1-50% flowering; 2-Anther colour; 3-No. of midges; 4-G1; 5-G2;
 6-Eggs/100 florets; 7-Larve/100 florets; 8-% grain damage; 9-Adult emergence;
 10-Earhead weight; 11-Grain yield/plant; 12-100 grain weight

correlation coefficients were higher than phenotypic correlation coefficients.

As has been brought out in the chapter on experimental results, the per cent grain damage exhibited strong positive correlation with number of larvae per hundred florets followed by number of eggs per hundred florets, adult emergence and number of adult midges per earhead at both phenotypic and genotypic level. The magnitude of association with larvae per hundred florets was high at both phenotypic and genotypic level in TAM2566 x SPV813 followed by DJ6514 x SPV829 and TAM2566 x SPV829. High magnitude of correlation for eggs per hundred florets is noticed in TAM2566 x SPV829 followed by TAM2566 x SPV813 and DJ6514 x SPV819. Grain damage exhibited high association with adult emergence at both phenotypic and genotypic level in DJ6514 x SPV829 followed by TAM2566 x SPV829 and TAM2566 x SPV813. Its magnitude of association with number of adult midges per earhead was found to be high in TAM2566 x SPV813 followed by DJ6514 x SPV829 at both phenotypic and genotypic level, while positively very low in TAM2566 x SPV829. According to Widstorm *et al* (1972), midge ratings were highly correlated with per cent grain damage. Melton and Teets (1984), Rossetto *et al.* (1984), Frankman and Page (1984) reported that more the number of

heritability accompanied by high GAM. Therefore, it should be possible to exercise intensive selection in the F_3 population to achieve considerable gain in identifying resistant types.

Study carried out among the three cross viz; DJ6514 x SPV829, TAM2566 x SPV813 and TAM2566 x SPV829 for twelve characters, the TAM2566 x SPV829 showed high heritability and high genetic advance over mean for number of eggs per hundred florets, number of larvae per hundred florets, earhead weight and grain yield per plant. Therefore, it should be possible to exercise more intensive selection in this cross to achieve considerable gain for these parameters.

5.4 Correlation studies

For making a rational improvement by employing proper selection strategies, one of the important parameters is per cent grain damage (dependent trait). The knowledge of correlation between the component characters and their association with the per cent grain damage is essential.

In the present study the phenotypic and genotypic correlation between per cent grain damage and other characters and also the interrelationship among themselves were considered. In general, it was observed that genotypic

ovipositing female midges per panicle more will be the per cent grain damage. Algali (1984) noticed that more the number of adult emergence per panicle more would be the chifffiness. According to Hogio *et al.* (1985) and Hogio and Ono (1986), per cent grain damage was highly correlated with incidence of midge between years. However, several other workers reported negative assoication between midge density and resistance level. (Chunderwar *et al.*, 1982; Waquil, 1986; Singh, 1987 and Sharma *et al.*, 1988). But such type of negative assoication was not seen in this cross.

Above results reveal that as magnitude of assoication of per cent grain damage was found to be high with larvae per hundred florets in TAM256 x SPV813 among three crosses, therefore, it is necessary to lay more emphasis in segregating population exhibiting less number of larvae followed by number of eggs, adult emergence and adult midges per panicle.

Per cent grain damage showed strong negative corelation with earhead weight and grain yield per plant and the magnitude was high in DJ6514 x SPV829 followed by TAM2566 x SPV813 and TAM2566 x SPV829. It revealed that lesser the per cent grain damage more would be the earhead weight and

vice versa. Obvious reason is earhead compactness may also serve to evaluate the level of resistance. Murthy and Subramaniam (1978) and Jadhav and Jadhav (1978) reported that genotype with compact earhead possess good amount of resistance.

Larvae per hundred florets indicated high association with eggs per hundred florets in TAM2566 x SPV829 followed by TAM2566 x SPV813 and DJ6514 x SPV829 at both phenotypic and genotypic level. Magnitude of association with adult emergence noticed was high in TAM2566 x SPV829 followed by DJ6514 x SPV829 and TAM2566 x SPV813. Larvae per hundred florets exhibited very low association both at phenotypic and genotypic level with adult midge per earhead in TAM2566 x SPV829 while in TAM2566 x SPV813 and DJ6514 x SPV829 it exhibited high association.

Magnitude of association of eggs per hundred florets with larvae per hundred florets noticed was high in TAM2566 x SPV829 at both the level followed by TAM2566 x SPV813 and DJ6514 x SPV829. Its association with midges per earhead was found to be high in DJ6514 x SPV829 at genotypic level and in TAM2566 x SPV813 at phenotypic level. However, low association was exhibited in TAM2566 x SPV829. It indicated

high magnitude of association with adult emergence in TAM2566 x SPV829 followed by TAM2566 x SPV813 and DJ6514 x SPV829. These results indicate more the heritability more could be larval numbers in florets and due to more survivability of larvae more will be the emergence.

Earhead weight per plant exhibited strong negative association and the magnitude of correlation at genotypic level was high with larve per hundred florets in DJ6514 x SPV829 followed by TAM2566 x SPV813 and TAM2566 x SPV829, while at phenotypically in TAM2566 x SPV829, TAM2566 x SPV813 and DJ6514 x SPV829. It indicated high magnitude of negative association with eggs per hundred florets in DJ6514 x SPV829 followed by TAM2566 x SPV829 and TAM2566 x SPV813 at genotypic level, and at phenotypic level in TAM2566 x SPV829, TAM2566 x SPV813 and DJ6514 x SPV829 in the descending order. Its magnitude of association with adult emergence was high at genotypic level in DJ6514 x SPV829 followed by TAM2566 x SPV813 and TAM2566 x SPV829. Earhead weight per plant exhibited high magnitude of negative association with number of adult midges per earhead in DJ6514 x SPV829 at both level while low association in other two crosses. These results revealed that high yielders have poor association with resistant parameters.

Earhead per plant showed strong positive association with grain yield per plant in all the three crosses. Similar results were also obtained by Nimbalkar *et al.* (1989).

Days to 50 per cent flowering and glume length- g_1 and g_2 showed no influence in all the three crosses.

5.5 Path coefficient analysis

The correlation coefficient only denote the total association existing between pairs of characters. Significant correlation values do not indicate direct or indirect relationship. Further when more parameters are included in a correlation study, often it affects the direct relationship with per cent grain damage and the indirect association become more complex. So, for a dependent trait like percent grain damage, it is desirable to find out the direct contribution of each character and indirect contribution of each made through its relationship with other components. Path analysis is useful in unravelling the direct effect of contributing traits per cent grain damage and their indirect effects through other components as it allows a detailed examination of specific forces acting to produce a correlation and measures the relative importance of each factor.

In view of this the phenotypic correlation coefficients among the characters were subjected for partition into direct and indirect effects on per cent grain damage in all the three crosses.

Obviously among all the parameters, it is the larvae per hundred florets which showed maximum positive direct effect on percent grain damage in all the crosses. Its effect was quite high (0.9913) in TAM2566 x SPV829 followed by DJ6514 x SPV829 (0.8714) and TAM2566 x SPV813 (0.7221). It clearly revealed that the larvae feed on developing grains and cause damage and hence primary cause for the chaffiness. Its indirect effect through number of eggs per hundred florets was low and positive in TAM2566 x SPV813, while in other two crosses negligible (either positive or negative). According to several workers, as a result of larval feeding there will not be development of grains which results in to chaffy earheads, (Subramanyam Iyer, 1922; Gable *et al.*, 1928; Cowland, 1936; Walter, 1941; Sheshagiri Rao, 1966; Parodi, 1966; Callon, 1969; Taley *et al.*, 1971 and Mote, 1985).

Number of eggs per hundred florets showed low positive direct effect on per cent grain damage in TAM2566 x SPV813; while, positive insignificant effects in DJ6514 x

SPV829 and negative insignificant effects were seen in TAM2566 x SPV829. According to Rossetto *et al* (1985), eggs are not the direct cause and all the eggs may not hatch because of short floral parts, and faster rate of grain development provides limited space and leads to the mortality of eggs. Its indirect effect masked through larvae per hundred florets and was high in all the three crosses, especially in TAM2566 x SPV829 which showed high effect (0.9483) followed by TAM2566 x SPV813 (0.6942) and DJ6514 x SPV829 (0.6324). Its indirect effect through other parameters are very less either positively or negatively in all the three crosses.

Number of adults midge per earhead showed positive low direct effect on per cent grain damage in TAM2566 x SPV813 and negative in TAM2566 x SPV829, while in DJ6514 x SPV829 it indicated negligible negative direct effect. This is because always number of adult midges may not be the true cause for the per cent grain damage. Probable reason could be the success of oviposition by the female midges for the per cent grain damage. Hence success in oviposition to a large extent determines the differences in genotypic resistance to the midge (Sharm *et al* 1990 b). Its direct effect was nullified through larva per hundred florets and was high in TAM2566 x SPV813 followed by DJ6514 x SPV829 and TAM2566 x SPV829. Its

indirect effect through other parameters was found to be very less either positively or negatively on per cent grain damage.

Number of adults emerged per earhead Showed negligible direct effect negative in DJ6514 x SPV829 and TAM2566 x SPV829, while it indicated positive low direct effect in TAM2566 x SPV813 on percent grain damage. Its direct effect was nullified through larva per hundred florets in all the three crosses which was very high in TAM2566 x SPV829 (0.7093) followed by DJ6514 x SPV829 (0.5636) and TAM2566 x SPV813 (0.3213). Anther colour showed positive low direct effect on per cent grain damage in TAM2566 x SPV813, whereas its direct effect was positive and insignificant in other two crosses. Its indirect effect was negligible (either positive or negative) through all other parameters in all the three crosses.

Glume length (g_1) showed positive high direct effect on per cent grain damage in TAM2566 x SPV813. These findings were in conformity with results obtained by Sharma *et al.* (1990). Its direct effect was negative and negligible in DJ6514 x SPV829 and positive significant in TAM2566 x SPV829. Its indirect effect through all other parameters was found to be very low, either positive or negative.

Glume length (g_2) indicated negative high direct effect on per cent grain damage in TAM2566 x SPV813. According to Sharma *et al.* (1990), glume length- g_2 indicated negative direct effect on per cent grain damage. In DJ6514 x SPV829, its direct effect was positive and low, while it was negative and low in TAM2566 x SPV829. Its indirect effect through all other parameters was found to be very low in all the three crosses.

Studies carried out on direct and indirect effects of different parameters on per cent grain damage in all the three crosses, clearly reveal that larvae per hundred florets had a potent role in causing chaffiness. This is evident by its high positive direct effect in TAM2566 x SPV829 (0.9913) followed by DJ6514 x SPV829 (0.8714) and TAM2566 x SPV813 (0.7221). In TAM2566 x SPV813 the glume length- g_1 also exhibited high positive direct effect on the per cent grain damage. Therefore, while making selection for desired resistant types in segregating population in all the three crosses prime consideration should be given to larvae per hundred florets. But greater emphasis should also be given to glume length- g_2 especially for TAM2566 x SPV813 population.

5.6 Future line of work

The parents used in the present study are a selected set of sorghum genotypes being maintained through selfing over generations. The priority for their selection rests with their reaction to midge activity and yielding ability. Thus, the information obtained on coefficient of variability of parents and their crosses, and genotypic and phenotypic coefficient of variation, heritability and genetic advance of crosses, association patterns of different midge resistant traits can very well be utilized in future breeding programme for resistance. Ultimate goal of such a breeding programme is to evolve the midge resistant genotype with increased yield and improved quality of the produce by any of the known methods of genetic manipulation.

In the present study least number of larvae, minimum glume lengths - (g_1 and g_2), least per cent grain damage and least adult emergence was recorded in DJ 6514. This genotype has already been used in developing the midge resistant variety ICSV 745. However the grain size of this genotype is relatively small. Therefore, efforts to increase the grain size are advisable. The parent TAM 2566 exhibited least number of adult midges per earhead, least per cent grain damage, least adult emergence and highest earhead weight and

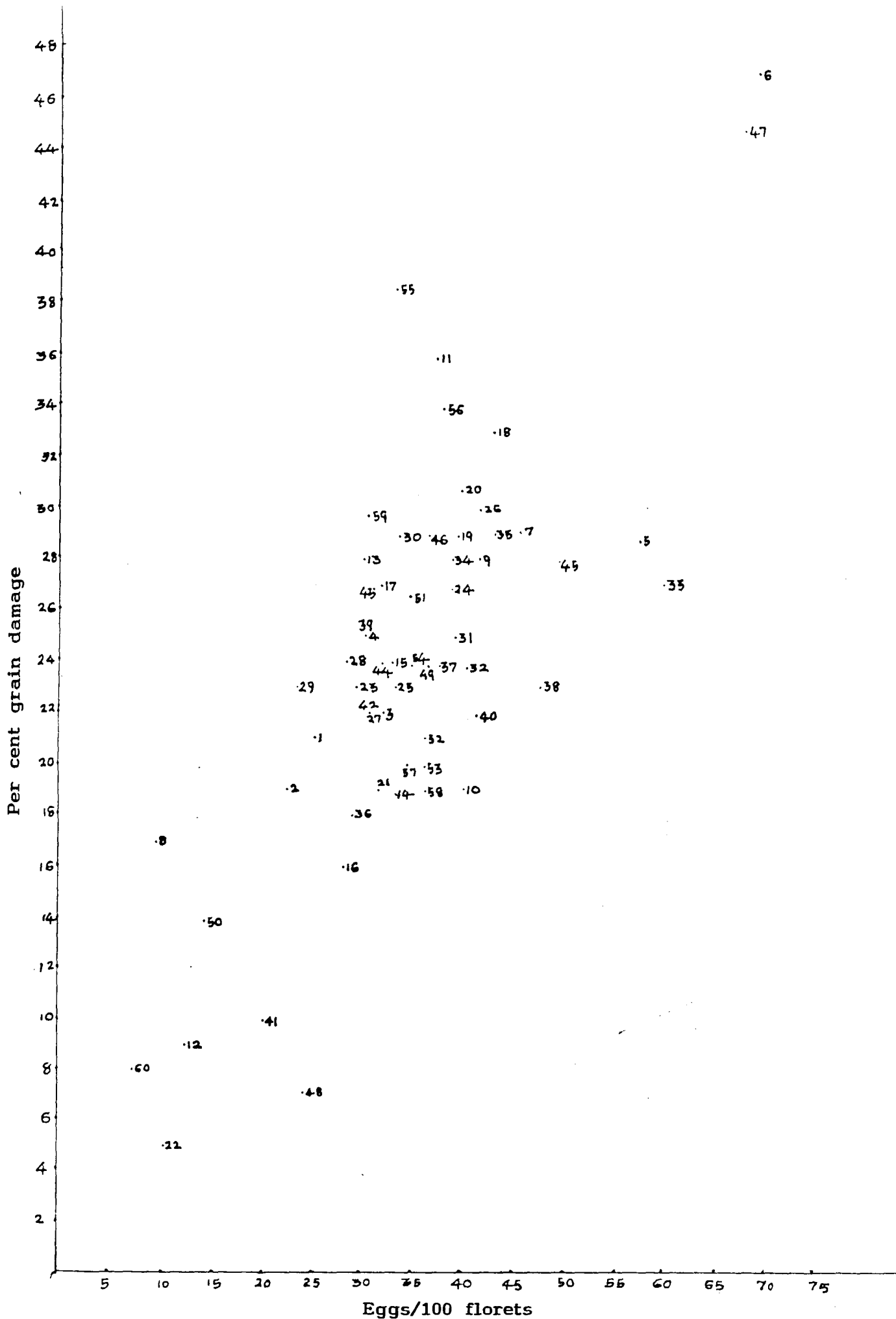


Fig. 7. Performance of plants in F_3 generation between per cent grain damage and eggs in DJ6514 x SPV829

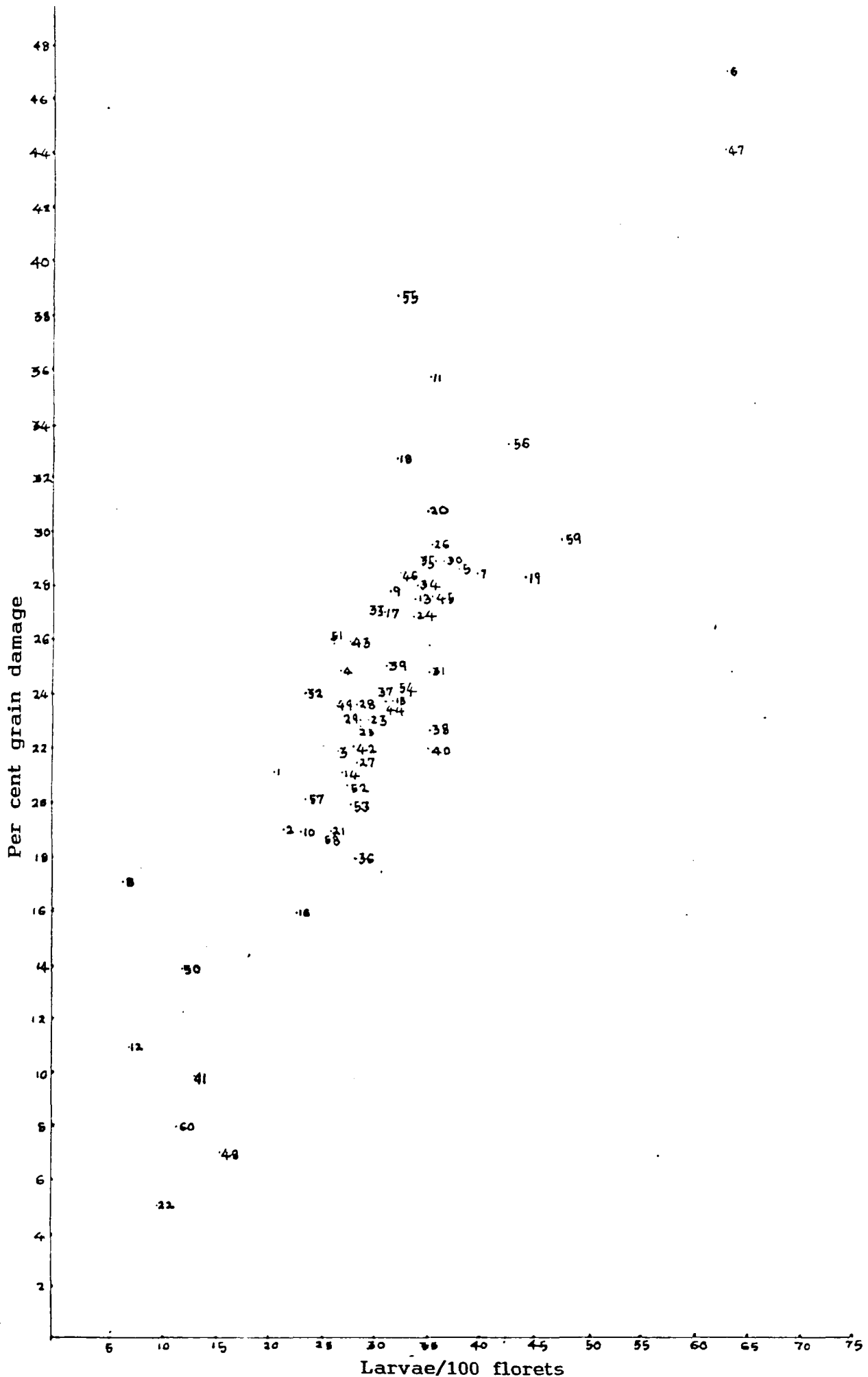


Fig. 8. Performance of plants in F_3 generation between per cent grain damage and larvae per hundred florets in DJ6514 x SPV829

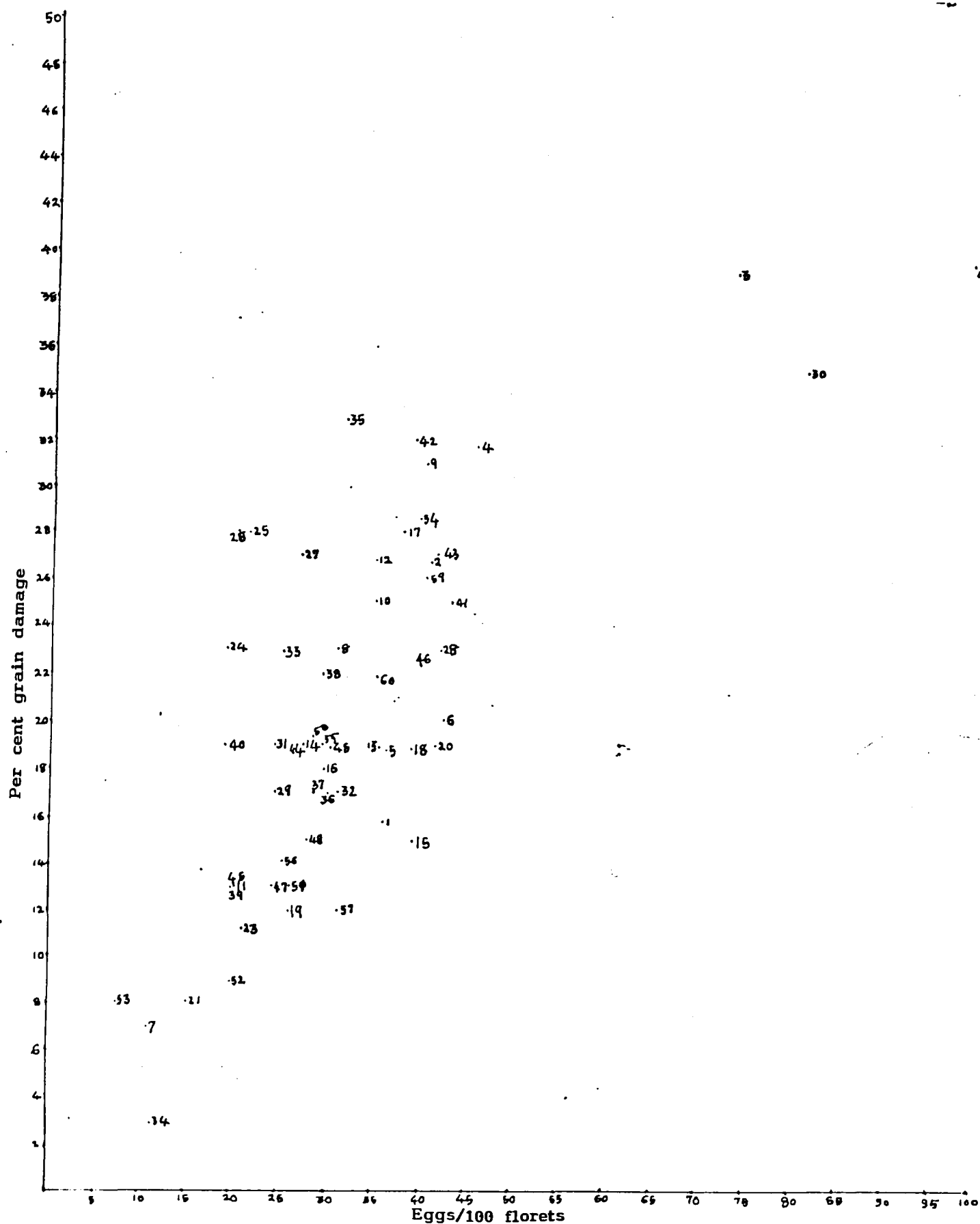


Fig. 9. Performance of plants in F_3 generation between per cent grain damage and eggs in TAM2566 x SPV813

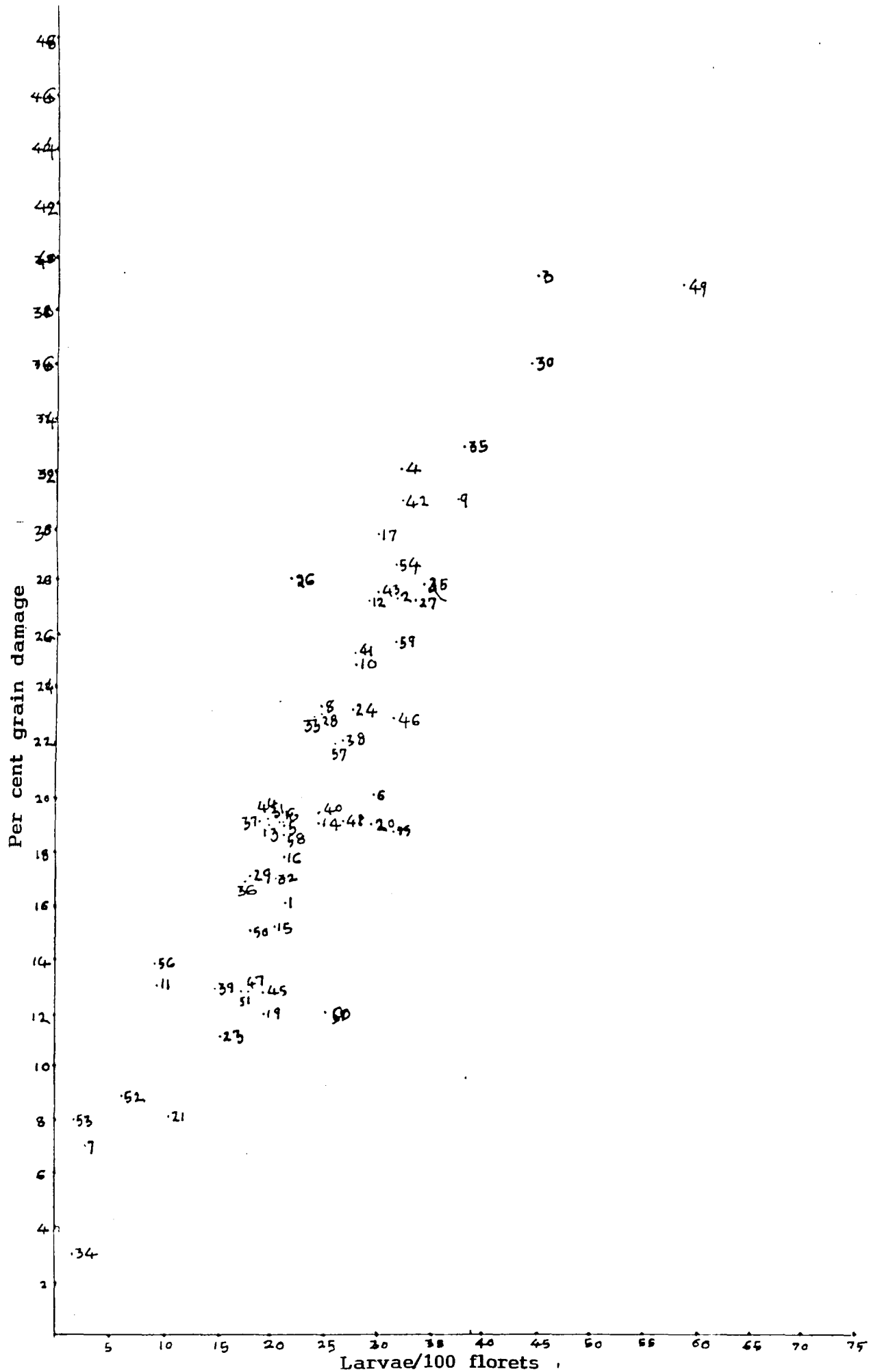


Fig. 10. Performance of plants in F_3 generation between per cent grain damage and larvae per hundred florets in TAM2566 x SPV813

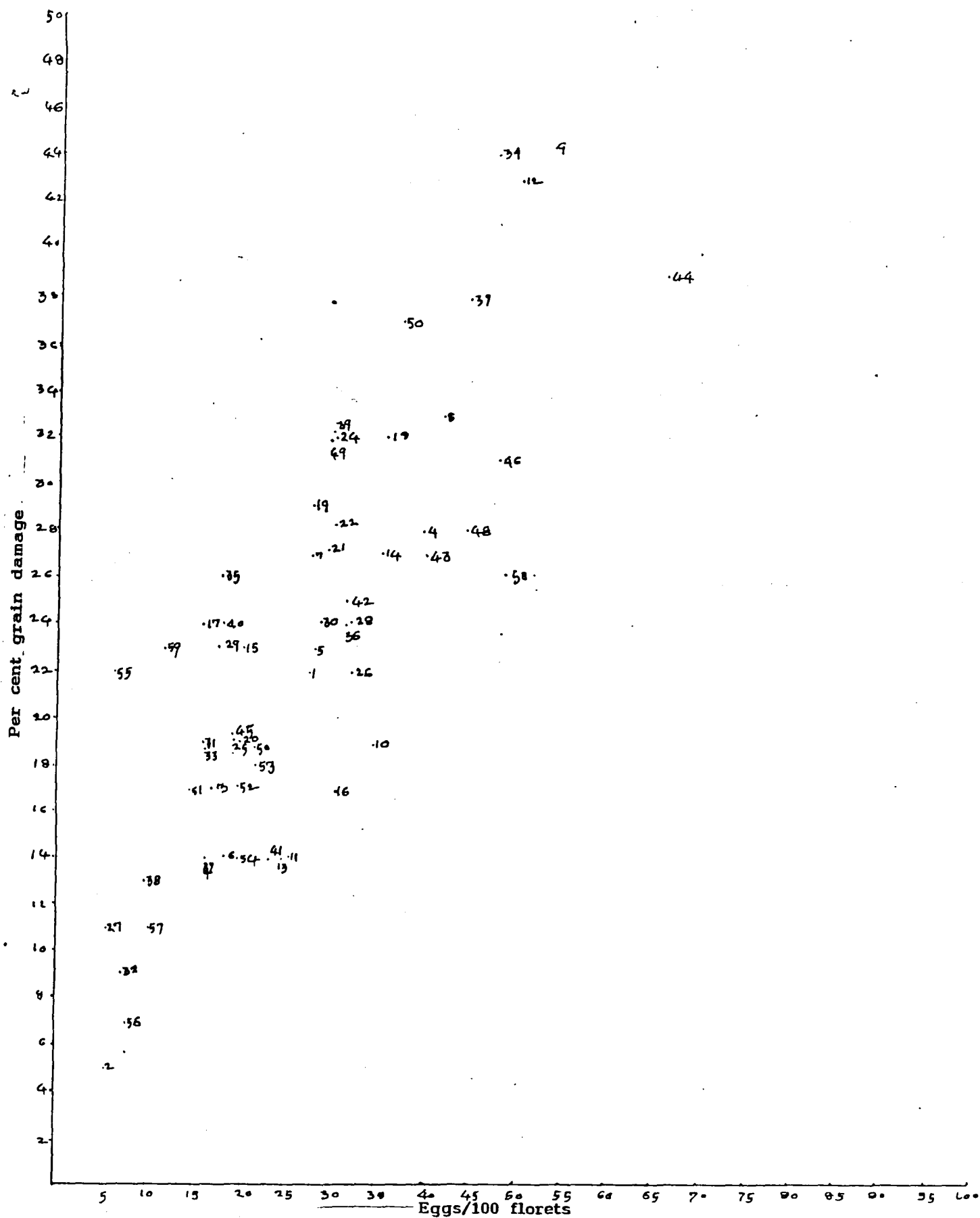


Fig. 11. Performance of plants in F_3 generation between per cent grain damage and eggs in TAM2566 x SPV829

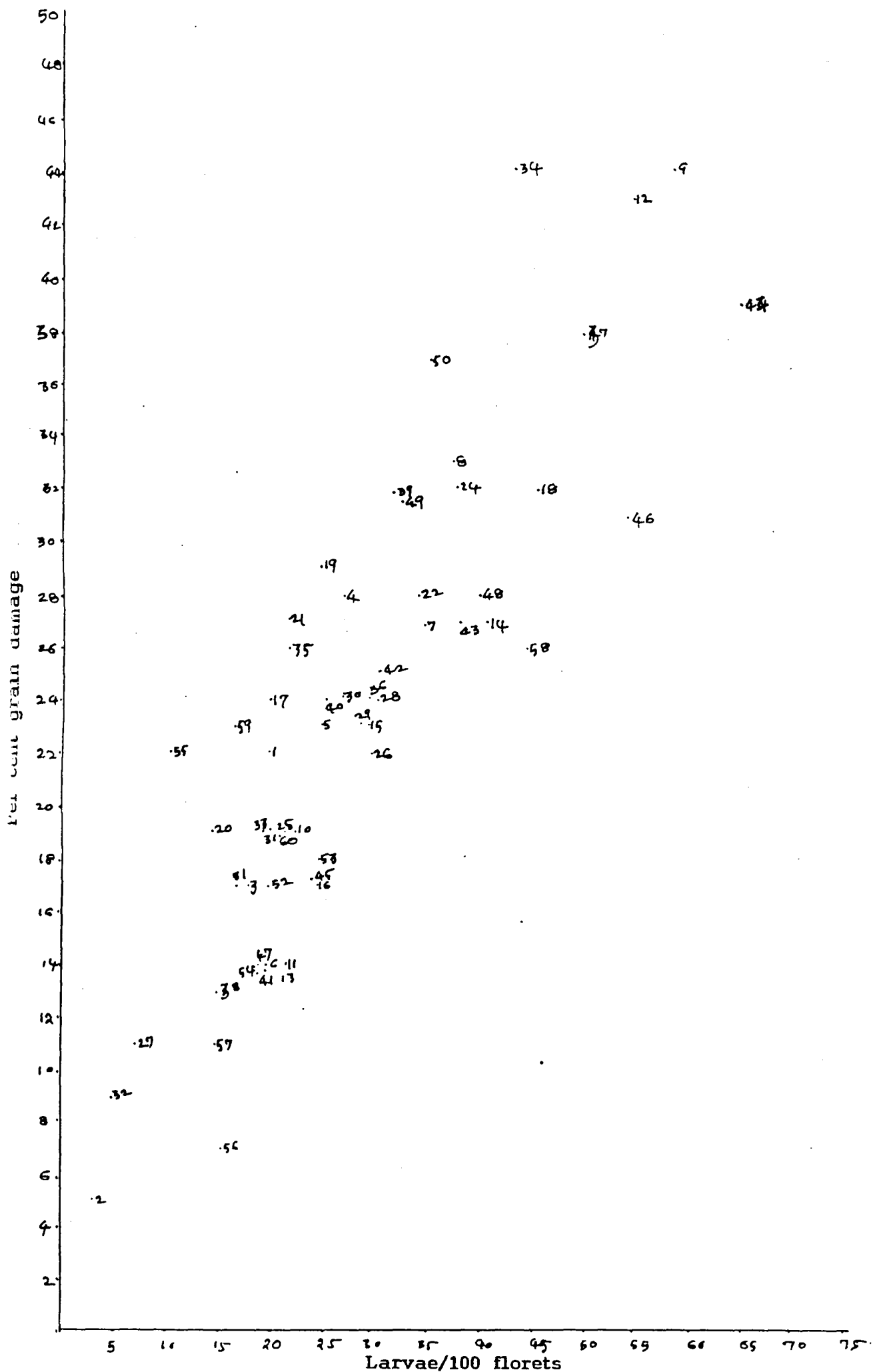


Fig. 12. Performance of plants in F₃ generation between per cent grain damage and larvae per hundred florets in TAM2566 x SDVR20

grain yield per plant. However, there is need for improvement of its grain colour.

Looking to the vast amount of genetic variability observed in the present study for midge resistant parameters, it should not be difficult to genetically improve resistant types. Among the traits, high genotypic coefficient of variation, higher heritability estimates coupled with high genetic advance were recorded for number of eggs per hundred florets and number of larvae per hundred florets in all the three crosses. From the Fig. 7 and 8 it can be observed that in the F_3 of DJ 6514 x SPV 829 per cent grain (14%) damage was least exhibited by as many as six plants and these plants also registered higher grain yield. It also revealed that plants which exhibited least parent grain damage had least number of eggs and least number of larvae per hundred florets. Similarly in F_3 of other two crosses viz., TAM 2566 x SPV 813 and TAM 2566 x SPV 829 the plants which had least per cent grain damage were 14 and 10, respectively as revealed in Fig. 9, 10, 11 and 12. Such plants with least damaged earheads contained less number of eggs and larvae. Out of these (14% grain damage) plants, least per cent grain damage (8%) was recorded in three plants from DJ6514 x SPV829, four from TAM2566 x SPV813 and two plants from TAM2566 x SPV829 cross.

Therefore, in such selected plants, it should be possible to obtain true breeding resistant types in population of succeeding generation. From all the considerations, F_3 families of TAM2566 x SPV813 and TAM2566 x SPV829 crosses were found to be of heritable characters for resistance and economic traits. These selections could be improved further in the successive generations by simple selection.

CHAPTER - VI

SUMMARY

VI. SUMMARY

The experimental material included three F_3 populations and their parents. The experiment with three replications was laid out during Kharif at the Main Research Station, 1990 University of Agricultural Sciences, Dharwad. Observations were recorded on twenty plants in each cross in each replication and on twenty plants in each parent on characters like days to fifty per cent flowering, anther colour, number of midges per earhead, glume length (g_1 , g_2), number of eggs per hundred florets, number of larvae per hundred florets, per cent grain damage, adult emergence, earhead weight per plant, grain yield per plant and hundred grain weight.

Estimates of interplant variability, phenotypic and genotypic variances, phenotypic and genotypic coefficient of variability, broad sense of heritability, genetic advance, phenotypic and genotypic correlations and path analysis were worked out.

Interplant studies among the parental strains revealed that least number of adult midges noticed on TAM 2566

followed by DJ 6514. Smallest glume length was exhibited by DJ 6514. Least number of eggs observed in TAM 2566, while lowest number of larvae were recorded in DJ 6514 followed by TAM 2566. The per cent grain damage and adult emergence was also minimum in DJ 6514. TAM 2566 also exhibited minimum per cent grain damage, adult emergence and higher yield. The facts indicated clearly the phenomena of non preference and antibiosis in both DJ 6514 and TAM 2566.

Among the three crosses, TAM 2566 x SPV 829 recorded high CV (5.59%). Least number of adult midges were recorded in TAM 2566 x SPV 813 followed by DJ 6514 x SPV 829 which exhibited CV values of 48.46 and 35.19 per cent respectively. Smallest glume length - g_1 was found in TAM 2566 x SPV 813 and g_2 in DJ 6514 x SPV 829. Minimum number of eggs were noticed in TAM 2566 x SPV 829 with a high coefficient of variability (53.67%). TAM 2566 x SPV 813 indicated minimum number of larvae (24.15) with a CV of 46.63 per cent. Least number of adult emergence was exhibited by TAM 2566 x SPV 813 (30.67) and DJ 6514 x SPV 829 (32.03). They also showed high variability, the CV being 33.63 and 29.28 per cent, respectively. Grain damage was least in TAM 2566 x SPV 813 with a mean per cent of 27.17 and CV of 23.98. TAM 2566 x

SPV829 indicated higher earhead weight (45.66 g). This cross also exhibited high grain yield with a mean of 31.40g and CV of 38.16 per cent. Hundred grain weight was high in TAM 2566 x SPV 829 with a mean value of 2.50g.

In general, anther colour, number of eggs per hundred florets and number of larvae per hundred florets showed maximum phenotypic and genotypic coefficient of variability in a DJ 6514 x SPV 829 and the values were 44.51, 34.37, 36.04 and 38.53, 31.28 and 33.53 per cent respectively. TAM 2566 x SPV 813 and TAM 2566 X SPV 829 exhibited high phenotypic and genotypic coefficient of variability for number of adult midges per earhead, number of eggs per hundred florets, and number of larvae per hundred florets.

Days to 50 per cent flowering and 100 grain weight were least influenced by environmental factors in all the three crosses as revealed by the narrow difference between phenotypic and genotypic variance for both traits.

High heritability estimates accompanied by high genetic advance over mean were noticed in the DJ 6514 x SPV 829 for glume length g_1 & g_2 , number of eggs per hundred florets and number of larvae per hundred florets. In TAM 2566 x SPV 813 high heritability estimates accompanied by high

genetic advance over mean were recorded for the number of adult midges per earhead, glume length- g_2 , number of eggs per hundred florets, number of larvae per hundred florets and grain yield per plant, while in TAM 2566 x SPV 829 high heritability estimates coupled with high genetic advance were recorded for number of adult midges per earhead, g_1 & g_2 , number of eggs per hundred florets and number of larvae per hundred florets.

Correlation studies indicated that per cent grain damage had high positive association at both phenotypic and genotypic level with larvae per hundred florets, eggs per hundred florets, adult emergence and adult midges per earhead in all the crosses. The magnitude of association with larvae per hundred florets was high in TAM 2566 x SPV 813 at both the phenotypic and genotypic level followed by DJ 6514 x SPV 829. Its association with eggs per hundred florets was very high in TAM 2566 x SPV 829. High magnitude of association with adult emergence was exhibited by DJ 6514 x SPV 829. Both the crosses DJ 6514 x SPV 829 and TAM 2566 x SPV 813 exhibited high association of per cent grain damage with number of adult midges per earhead, while in TAM 2566 x SPV 829 association was found to be very low.

High negative association of per cent grain damage were noticed with earhead weight per plant and grain yield per plant at both phenotypic and genotypic level in all the three crosses.

The direct and indirect effects of different traits on per cent grain damage were studied through path coefficient analysis. Among all the traits, it was the larvae per hundred florets which showed high positive direct effect in all the three crosses, viz., TAM 2566 x SPV 829, DJ 6514 x SPV 829 and TAM 2566 x SPV 813 and indirect effect via eggs per hundred florets, adult emergence and number of adult midges per earhead. In TAM 2566 x SPV 813 glume length g_1 , also exhibited high positive direct effect. Therefore, it is suggested to lay more emphasis on larvae per hundred florets in all the three crosses, while in TAM 2566 x SPV 813 the prime consideration should not be given to larvae per hundred florets only but also to glume length $-g_1$.

Some plants in the F_3 progeny of three crosses were found outstanding in respect of important parameters like eggs per hundred florets, larvae per hundred florets and per cent grain damage. Performance of plants for eggs per hundred florets and larvae per hundred florets were plotted against

per cent grain damage. From this analysis four plants in TAM 2566 x SPV 813, two plants in TAM 2566 x SPV 829 and three in DJ 6514 x SPV 829 which exhibited least per cent grain damage were identified for obtaining true breeding resistant types in succeeding generation by performing simple selection.

CHAPTER - VII

REFERENCES

VII. REFERENCES

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APPENDIX

Appendix . Per cent grain damage

Plant numbers	DJ2514 x SPV829	TAM2566 x SPV813	TAM2566 x SPV829
1	21 (27.28)	16 (25.58)	22 (27.28)
2	19 (23.84)	27 (31.31)	5 (12.92)
3	22 (27.97)	39 (38.65)	17 (24.35)
4	25 (30.00)	32 (34.45)	28 (31.95)
5	29 (32.21)	19 (25.84)	23 (28.66)
6	47 (43.28)	20 (26.56)	14 (21.97)
7	29 (32.58)	7 (15.34)	27 (31.31)
8	17 (24.35)	23 (28.66)	33 (35.06)
9	28 (31.95)	31 (33.83)	44 (41.56)
10	19 (25.84)	25 (30.00)	19 (25.84)
11	36 (26.87)	13 (21.13)	14 (21.97)
12	9 (17.46)	27 (31.31)	43 (40.98)
13	28 (31.95)	19 (25.84)	14 (21.97)
14	19 (25.84)	19 (25.84)	27 (31.31)
15	24 (29.33)	15 (22.79)	23 (28.66)
16	16 (28.58)	18 (25.10)	17 (24.35)
17	27 (31.31)	28 (31.95)	24 (29.33)
18	33 (35.06)	19 (25.84)	32 (34.45)
19	29 (32.58)	12 (20.27)	29 (32.53)
20	31 (33.83)	19 (25.84)	19 (25.84)
21	19 (25.04)	8 (16.43)	27 (31.31)
22	5 (12.92)	59 (50.18)	28 (31.95)
23	23 (28.66)	11 (19.37)	53 (46.72)
24	27 (31.31)	23 (28.66)	32 (34.45)
25	21 (27.28)	28 (31.95)	19 (25.84)
26	30 (33.21)	28 (31.95)	22 (27.97)
27	22 (27.97)	27 (31.31)	11 (19.37)
28	24 (29.33)	23 (28.66)	24 (29.33)
29	23 (28.86)	17 (24.35)	23 (28.66)
30	29 (32.58)	36 (36.87)	24 (29.33)
31	25 (30.00)	19 (35.84)	19 (25.84)
32	24 (29.33)	17 (24.35)	9 (17.46)
33	27 (31.31)	23 (28.66)	19 (25.84)
34	28 (31.95)	3 (9.98)	44 (41.55)
35	29 (32.58)	35 (35.06)	26 (30.66)
36	18 (25.80)	17 (24.35)	24 (29.33)
37	24 (29.33)	17 (24.35)	38 (38.06)
38	23 (28.66)	22 (27.97)	13 (21.13)
39	35 (30.00)	13 (21.13)	32 (34.45)
40	22 (27.97)	19 (25.84)	24 (29.33)
41	10 (18.44)	25 (30.00)	14 (21.97)
42	22 (27.97)	31 (33.83)	25 (30.00)
43	25 (31.31)	27 (31.31)	27 (31.31)
44	24 (29.33)	19 (25.84)	39 (38.65)
45	28 (31.85)	13 (21.13)	17 (24.35)
46	29 (32.58)	23 (28.66)	31 (33.83)
47	45 (42.13)	13 (21.13)	14 (21.97)
48	7 (15.34)	19 (25.84)	28 (31.95)
49	24 (29.33)	39 (38.65)	32 (34.45)
50	14 (21.97)	15 (22.79)	37 (37.47)
51	27 (31.31)	13 (21.13)	17 (24.35)
52	21 (27.28)	9 (17.46)	17 (24.35)
53	20 (26.56)	8 (16.43)	18 (25.10)
54	24 (29.33)	29 (32.58)	14 (21.97)
55	39 (38.65)	19 (25.84)	22 (27.97)
56	34 (35.67)	14 (21.97)	7 (15.34)
57	20 (26.56)	22 (27.97)	11 (19.37)
58	19 (25.84)	19 (25.84)	26 (30.66)
59	30 (33.21)	26 (30.66)	23 (28.66)
60	8 (16.43)	22 (27.97)	19 (25.84)

Figures in parenthesis are arc-sin transformed values

Evaluation of F_3 population of sorghum against earhead midge
(Contarinia sorghicola, Coquillett) resistance

M.H. TATAGAR

1994

Major Advisor:

Dr. S. LINGAPPA

ABSTRACT

An experiment involving three F_3 populations viz., DJ6514 x SPV 829, TAM 2566 x SPV 813, TAM 2566 x SPV 829 and their parents was laidout in randomized ~~complete~~ block design during Kharif 1990 at M.R.S., UAS, Dharwad to estimate the interplant variability, phenotypic and genotypic variances, phenotypic and genotypic coefficient of variability, broad sense heritability, genetic advance, phenotypic and genotypic correlation of midge resistant parameters, the direct and indirect influence of different resistant characters.

Interplant studies among parental strains revealed that least number of eggs observed in TAM 2566 while, lowest number of larvae recorded in DJ 6514 followed by TAM 2566. The per cent grain damage and adult emergence was also minimum in DJ 6514 and TAM 2566. These facts indicated clearly the phenomina of non-preference and antibiosis in both DJ 6514 and TAM 2566.

Among the three crosses minimum number of eggs were noticed in TAM 2566 x SPV 829 with a high coefficient of variability (53.67%). TAM 2566 x SPV 813 indicated minimum number of larvae (24.15) with a ^a CV of 46.63 per cent. Least number of adult emergence was exhibited by TAM 2566 x SPV 813 (30.67) and DJ 6514 x SPV 829 (32.03). Among all the characters eggs per 100 florets and larvae per 100 florets exhibited high of gcv and pcv in all the three crosses.

High heritability estimates accompanied by high genetic advance recorded for ^{number of} eggs per 100 florets and number of larvae per 100 florets in all the three crosses revealed that these characters are governed by additive gene action.

Correlation studies indicated that per cent grain damage had high ~~xxxx~~ positive association at both phenotypic and genotypic levels with larvae per 100 florets, eggs per 100 florets, adult emergence and adult midges per earhead in all the three crosses. The magnitude of association with larvae per 100 florets was high in TAM 2566 x SPV 813 followed by DJ 6514 x SPV 829 and TAM 2566 x SPV 829.

The direct and indirect effects of different traits on per cent grain damage revealed that among all traits, it was the larvae per 100 florets which showed high positive direct effect in all the three crosses and indirect effects via eggs, adult emergence and number of adult midges per earhead. Hence in selecting true breeding resistant types prime consideration should be given to larvae per 100 florets in all the three crosses.

Performance of plants in F_3 progeny of three crosses with respect to resistant traits indicated that three plants in DJ 6514 x SPV 829, four in TAM 2566 x SPV 813 and two plants in TAM 2566 x SPV 829 were ~~ka ka~~ found to be outstanding as evidenced by their least per cent grain damage (8%). Therefore, such selected ^{these} plants could be utilised in succeeding generation to obtain resistant types by performing simple selection.

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ಗಾ.ಕೃ.ವಿ.ಕೆ, ಬೆಂಗಳೂರು - ೫೬

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