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Inheritance of Fusarium wilt and Qualitative and Quantitative Characters in Chilli (Capsicum Annuum L)

D.G. Manu, B.V. Tembhurne[1], B. Kisan, D.S. Aswathnarayana and J.R.Diwan

Abstract

Inheritance of resistance to Fusarium wilt was studied by using three crosses viz., SNK x P3, JAJPUT x P3 and KA2 x P3 to initiate the breeding programme so, as to minimize the chemical fungicidal sprays on the crop. Study on Inheritance of resistance to *Fusarium* wilt caused by Fusarium solani is conditioned by a single dominant gene. The inheritance of anther, pollen, fruit colour and fruit direction was also controlled by single dominant gene except style colour which was controlled by complementary genes. The estimates of scaling tests along with gene effects based on six parameter models for the cross, detected the presence of additive and dominance gene effect for fruit length, additive gene effect for fruit weight but there were no gene effects found for fruit diameter. In addition to this fruit length exhibited predominance of additive x additive gene effects. Hence, the breeding method used to exploit additive gene action, such as simple selection technique or hybridization followed by pedigree breeding method is suggested for improvement of these traits.

Keywords: Fusarium wilt, Chilli, Capsicum, Inheritance

1.1 Introduction

India is the largest producer and exporter of spices in the world. In the world chilli production covers an area of 1.9 million hectares with a production of 29.9 million tonnes averaging a productivity of 15.8 tonnes per hectare.

India is the major producer, consumer and exporter of chilli, covering an area of 0.77 million hectares with a production of 0.659 million tonnes averaging a productivity of 0.86 tonnes per hectare (Anon., 2013). University of Agricultural Sciences, Raichur, Karnataka, India.

[1] Email: bvtembhurne@gmail.com.

It is an indispensable spice essentially used in every Indian cusine due to its pungency, taste, appealing odour and flavour. Chilli fruits are rich sources of vitamin A, C and E. Pungency of chilli is due to a crystalline acrid volatile alkaloid called capsaicin, present in the placenta of fruit. It is also a good source of chilli oleoresin, which is the total flavour extract of dried and ground chillies and concentrated in homogenous free flowing product, which has varied uses in processed food and beverage industries. The natural colour extracts of chilli are also finding their increased value in place of artificial colours in the food items, especially in the developed nations. In the diet of poor people in India, chilli plays a major role in providing ascorbic acid in sufficient quantity and Carotene, the yellow pigment is a provider of vitamin A.

The crop suffers from many pest and diseases among these diseases wilt, anthracnose or fruit rot or die back, murda complex, leaf spot, and powdery mildew are majar problems. Wilt caused by *Fusarium solani* is becoming more serious in chilli growing tracts of India (Singh *et al.* 1998) and perticularly in Karnataka particularly in black cotton soil leading up to 25 per cent yield loss (Madhukar and Naik, 2004). The incidence of wilt varied from 0 to 75 per cent in different states of India (Anon., 2005).

Being soil borne, the control of this disease by chemical methods is very difficult without adverse effect on the physico-chemical and biological properties of soil, it is imperative to develop cultivars with inbuilt resistance to this disease. Since the disease has threatened cultivation of chilli crop, the preliminary work to find resistance sources of this disease was initiated about a decade ago (Ahmed *et al*., 1994). The genotypes identified as resistance to a particular pathogen may not necessarily have desirable agronomic traits and thus, may not be directly introduced for wide scale cultivation but can be used as donors for resistance genes under breeding programme.

Further the knowledge of inheritance of various characters of qualitative and quantitative nature is important to achieve success in plant breeding in general and chilli breeding in particular. The inheritance of characters like fruit, style, pollen, anther colour and fruit direction would be valuable information to breeders while selecting superior genotypes for desirable traits. Hence, the study was designed to understand the inheritance of resistance to *Fusarium* wilt and other characters like fruit, style, pollen, anther colour and fruit direction were investigated.

1.2 Justification

Fusarium wilt is a typical soil borne disease and the fungus survives for several years in soil. The pathogen is extremely adaptable, variable and capable of long persistence in the soil in the form of chlamydospores. The general use of resistant cultivars as a means of controlling fungal wilts has been extremely successful. The resistant variety is always one of the best way and will go a long way in reducing loss due to wilt diseases. Identification of diverse and stable field source of resistance to *Fusarium* wilt is imperative and pre-requisite to a resistance breeding programme. The use of resistant variety is essential not only in reducing losses due to disease, but also in avoiding fungicidal toxicity which is likely to occur due to their application to soil. Further, the inheritance studies for quantitative and quantitative traits are also important to improve the crop qualitatively and quantitatively. Most of the characters studied were distinct in nature. Hence, there is further scope to improve these characters in chilli through selection or exploiting heterosis.

1.3 Study Area

The present investigation on *Fusarium* wilt of chilli was carried out during 2013-2014 at the Department of Genetics and Plant Breeding and Department of Plant Pathology Raichur. Raichur is situated in North Eastern dry zone (Zone 2) of Karnataka state at 16^{o} $11^{'}$ N latitude, 77^{o} $20^{'}$ East longitude with an altitude of 389 meter above the mean sea level.

1.4 Methodology

1.4.1 Inheritance of Resistance to *Fusarium* Wilt.

All glassware's and liquid media were subjected to sterilization by autoclaving at 1.1 kg/cm^2 (121.6 ^{0}C) for 20 minutes. The plant tissues were surface sterilized in 1:1000 mercuric chloride solution followed by three changes in sterile water.

1.4.2 Mass Multiplication of *Fusarium* on PDA

The fungus was mass multiplied on potato dextrose broth (PDB). 100 ml of PDB was taken into 250 ml conical flask and autoclaved at 1.1 kg/cm^2 for 20 minutes.

The mycelial disc cut from the margin of a week old culture grown on Petri dish was inoculated into PDB under aseptic conditions. The flasks were incubated at 28±1^0 C for 15 days. The mycelium mats were collected after 15 days by filtering with Whatman No 42 filter paper disc of 12.5 cm diameter and washed with sterile water. The spore suspension was prepared using waring blender to disturb the spores in sterile water and filtered through cheese-cloth before use and spore load ml^{-1} was computed by using a Haemocytometer.

1.4.3 Pathogenicity test by Rapid root dip Transplanting Technique

Rapid root dip transplanting technique method developed by Naik *et al.* (1996). Chilli seedlings were raised in a plastic trays containing sterilized sand in a nylon net house and protected with two insecticidal sprays of Malathion (0.1%) and Monocrotophos (0.05%) to prevent the viral disease. Three weeks old seedlings were removed, roots thoroughly washed in running tap water and 3mm tip of roots were cut and immersed in spore suspension of *F. solani* and planted in a plastic bags containing sterilized soil. Then plants were planted in plastic bags and maintained. In cases where isolates produced typical wilting symptoms, the fungus was successfully re-isolated and Koch's postulates proved.

1.4.4 Sick Pot Technique

The sick pots were prepared by sterilizing the soil in autoclave and the soil was inoculated with mass multiplied *Fusarium* culture for ten days in order to build up the inoculums load in the soil, then the twenty five days old plants were planted in the pots and observations were recorded for resistant or susceptible characters. The fungus was successfully re-isolated and Koch's postulates proved.

The plant survival data as on 30 DAT were utilized to ascertain the genetics of *Fusarium* wilt disease. Plant survival (%) was calculated as:

$$\text{Plant survival (\%)} = \frac{\text{Number of healthy plants in the last recording}}{\text{Number of plants established}} \times 100$$

1.4.5 Experimental Material

The crosses SNK x P3, KA2 x P3 and RAJPUT x P3 were used for *Fusarium* wilt inheritance study. However, KA2 x P3, RAJPUT x P3, 9608U x K1-4D, JNB1 x RAJPUT and 9608U x KA2 were used for qualitative characters like fruit colour, style colour, pollen colour, anther colour and fruit direction. While, SNK x P3 was used for fruit length (cm), fruit diameter (cm) and fruit weight (g).

1.5 Results and Discussion

1.5.1 Genetics of *Fusarium* wilt Resistance

The inheritance of resistance to *Fusarium* wilt was studied in three crosses *viz.,* SNK x P_3, KA_2 x P_3 and RAJPUT x P_3. The per cent disease incidence (PDI) and their reaction to *Fusarium* wilt in parents and F_1 generation for all three crosses are presented in Table 1. Out of 48 plants transplanted in the sick pots four plants were wilted, with the 8.33 PDI indicated resistance reaction to *Fusarium* wilt for parent P_3. Among the 53, 45 and 51 total plants for the parents SNK, RAJPUT and KA2 24, 21 and 19 plants were wilted with PDI of 45.28, 46.66 and 37.25 respectively showed susceptible reaction to *Fusarium* wilt.

Whereas hybrid SNK x $P_{3,}$ RAJPUT x P_3 and KA_2 x P_3 recorded 9.75, 8.92 and 5.26 PDI indicated resistant reaction to *Fusarium* wilt. In F_2 generation, 280: 83, 241:71 and 266: 81 plants showed resistant: susceptible reaction for the cross SNK x $P_{3,}$ KA_2 x P_3 and RAJPUT x P_3 respectively. Approximate ratio registered for all the three crosses was 3 resistant: 1 susceptible. The inheritance pattern in all the three crosses clearly showed that resistance was governed by single dominant gene (Jabeen et al, 2007).

Table 1: Per Cent Disease Incidence of Parents and Hybrids and Their Reaction to *Fusarium* wilt in Chilli

Parents	Number of wilted plants	Total number of plants planted	PDI (%)	Reaction
P_3	4	48	8.33	Resistant
SNK	24	53	45.28	Susceptible
RAJPUT	21	45	46.66	Susceptible
KA_2	19	51	37.25	Susceptible
Hybrids				
SNK X P_3	4	41	9.75	Resistance
RAJPUT x P_3	5	56	8.92	Resistance
KA_2 X P_3	2	38	5.26	Resistance

1.5.2 Inheritance of Some Qualitative Characters

The inheritance of anther colour, pollen colour, style colour, fruit colour and fruit direction was studied in different crosses and presented in Table 2. In the F_1 generation all the plants showed cream anther for the cross KA_2 X P_3. However, F_2 generation showed the approximated ratio of cream to light blue anther was 3:1 which indicated that this trait is controlled by monogenic dominant gene with typical feature of qualitatively inherited character and of full dominance over recessiveness. As the light blue anther controlled by recessive genes, it expressed when the genotypes will be in homozygous condition (Tiem, 1975; Huff, 1991; Zhang and Hallauer, 1996; Yang and Park, 1998).

The pollen colour in F_2 generation recorded 148 plants with cream pollen whereas remaining 51 plants had white pollen.

The ratio of cream to white pollen is nearly equal to 3:1 indicated that pollen colour is controlled by a mono gene (Stoenescu, 1974; Qiao et al, 1993; Wang and Wang, 1994; Qiao chungui et al, 1995).

All the plants in the F_1 generation showed blue style in crossing between 9608U (blue) and K1-4D (white) style parents, indicated that blue style was dominant over while. The segregating ratio for this trait was 9 blue : 7 white style suggested that it was controlled by complementary genes with the close agreement between observed and expected frequencies.

Contrasting genotypes, JNB_1 (Red) and RAJPUT (Yellow) were crossed to study the fruit colour. The F_1 plants had red fruit colour, indicated typical feature of qualitatively inherited character and of full dominance over recessiveness (Elizanilda et al, 1999; Deshpande, 1932; Ramanujam, 1965). Therefore, the red fruit was monogenic dominant over yellow fruit colour. In F_2 generation, the ratio of red fruit plants to yellow fruit plants approximated 3:1.

The inheritance of fruit direction was studied by involving two parents having contrasting fruit direction 9608D (Erect) X KA_2 (Pendent). All the F_1 plants had pendent fruit direction. In F_2 generation the ratio of pendent to erect fruit plants approximated 3:1 indicated that the fruit direction is controlled by a mono gene (Kaiser, 1935; Ramanujam, 1965; Bagavandoss, 1980; Sayed and Bagavandas, 1980; Deshpande, 1932).

Table 2. Segregation Pattern for *Fusarium* Willt and Qualitative Characters in Chilli

Characters/Crosses	F1	F2 Generation									
Fusarium wilt		Resistant		Susceptible		Total		Ratio	X^2 Value	P Value	Type of gene action
		Obs	Exp	Obs	Exp	Obs	Exp				
SNK X P3	Resistant	280	272.25	83	90.75	363	363	3:1	0.88	0.34	Monogenic dominant
KA2 X P3	Resistant	241	234	71	78	312	312	3:1	0.83	0.36	Monogenic dominant
RAJPUTXP3	Resistant	266	260.25	81	86.75	347	347	3:1	0.50	0.47	Monogenic dominant
Anther colour		Cream		Light blue							
KA2 X P3	Cream	144	147	52	49	196	196	3:1	0.24	0.62	Monogenic dominant
Pollen colour		Cream		White							
RAJPUTXP3	Cream	148	149.25	51	49.75	199	199	3:1	0.04	0.83	Monogenic dominant
Style colour		Blue		White							
9608UXK1-4D	Blue	123	123.75	97	96.25	220	220	9:7	0.01	0.92	Complementary
Fruit colour		Red		Yellow							
JNB1XRAJPUT	Red	161	160.5	53	53.5	214	214	3:1	0.006	0.93	Monogenic dominant
Fruit direction		Pendent		Erect							
9608UX KA2	Pendent	152	153	52	51	204	204	3:1	0.025	0.87	Monogenic dominant

Obs: Observed Frequency and Exp: expected Frequency

1.5.3 Estimates of Gene Action for Quantitative Characters

Mean and variances of six generation were mentioned in Table 3 and estimates of scaling test and various genetic effects studied with respect to three fruit characters are documented in Table 4. The F_1 means of the cross laid between its parental lines for the traits fruit length, fruit diameter and fruit weight indicating the incomplete dominance for these characters (Table 3). F_2 and back cross generation means also laid between parental lines for all three traits.

Table 3: Mean (± SE) and Variance Values of Six Generations for Fruit Characters

Generations	Sample size(K)	Fruit length		Fruit diameter		Fruit weight	
		Mean	Variance	Mean	Variance	Mean	Variance
P_1	15	18.55±0.25	0.95	0.93±0.07	0.06	1.01±0.08	0.06
P_2	15	5.10±0.31	1.42	1.27±0.07	0.07	0.35±0.04	0.02
F_1	15	9.49±0.30	1.33	1.11±0.08	0.10	0.64±0.02	0.01
F_2	60	7.74±0.21	2.69	1.18±0.05	0.14	0.59±0.03	0.06
BC_1	30	11.33±0.25	1.88	1.24±0.06	0.10	0.75±0.04	0.04
BC_2	30	7.71±0.20	1.14	1.17±0.06	0.10	0.48±0.02	0.01

P_1: Parent 1, P_2: Parent 2, F_1: First filial generation, F_2: Second filial generation, BC_1: Back cross 1 and BC_2: Back cross 2

1.5.4 Scaling and Joint Scaling Test

The significant values of A, C and D scaling tests for fruit length indicated the presence of all three types of non-allelic interactions viz., additive x additive, additive x dominance and dominance x dominance for this character (Patil, 2011; Prajapati et al, 2012). However, traits like fruit diameter and fruit weight recorded non-significant scaling test values reveals absence of epistasis for these characters (Table 4). The additive gene effects had a predominant role in the inheritance of fruit length (Awasthi et al, 1976; Kamboj et al, 2006; Patil, 2011; Patil et al, 2012: Prajapati et al, 2012). In addition to this fruit length exhibited predominance of dominance and additive x additive gene effects. However, fruit weight showed predominance of additive effect (Kamboj et al, 2006; Prajapati et al, 2012).

Table 4. Estimates of Gene Effects for Fruit Traits in Chilli Using Six Parameter Model

Tests	Cross SNKXP3		
Scaling test	**Fruit length**	**Fruit diameter**	**Fruit weight**
A	-5.37±0.63**	0.45±0.16	-0.15± 0.11
B	0.83±0.58	-0.04±0.16	-0.03±0.06
C	-11.68±1.11**	0.32±0.27	-0.26±0.16
D	-3.57±0.53**	-0.04±0.13	-0.04±0.08
Gene effects			
m	7.74±0.21**	1.18±0.05**	0.59±0.03**
(d)	3.62±0.32**	0.07±0.08	0.27±0.04**
(h)	4.81±1.12**	0.09±0.27	0.05±0.16
(i)	7.15±1.06**	0.08±0.26	0.09±0.16
(j)	-3.10±0.38	0.24±0.10	-0.06±0.06
(l)	-2.61±1.69	-0.49±0.43	-0.09±0.23
Type of epistasis	Duplicate	Duplicate	Duplicate

m=mean, d=additive effect, h= dominance effect, i= additive x additive type gene interaction,
j= additive x dominance type gene interaction and l= dominance x dominance type gene interaction. * P<0.05, ** P<0.01 respectively.

1.6 Conclusion

It has been concluded from the present study that genetics of *Fusarium* wilt resistance as well as qualitative characters like anther, pollen, fruit colour and fruit direction were monogenic dominant in nature. However, the style colour inheritance was controlled by complementary genes. The fruit length was controlled by both dominant as well as additive genes suggested the heterosis breeding and recurrent selection. While fruit weight is governed by only additive effects indicated the improvement through pedigree method of selection. The inheritance of *Fusarium* wilt resistance was monogenic dominance in nature hence, heterosis breeding is advocated to boost the yield and avoid the chemical fungicidal sprays to control the disease thereby saving the crop and environmental pollution.

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