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Combining ability in bacterial wilt resistant chilli (*Capsicum annuum* L.) genotypes

N.S. James, S. Nirmala Devi* and S. Krishnan

Department of Olericulture, Kerala Agriculture University,
Thrissur-680 656, Kerala, India.
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ABSTRACT

The experiment was conducted with five bacterial wilt resistant genotypes *viz.* Ujwala. Anugraha, VKC 2, VKC 11 and VKC 76 were crossed in diallel design without reciprocals to obtain ten F_1 hybrids. The good general combiner for the number of fruits per plant and yield was Anugraha. Ujwala and Anugraha were found to be good general combiners for the content of phosphorus, calcium, magnesium and beta carotene. VKC 11 showed high general combining ability in fruit length, fruit girth, magnesium, iron, vitamin C and beta carotene. All the cross combinations showed earliness in flowering, Ujwala x VKC 11 were found best specific combiner for fruit width, fruit girth, average fruit weight, vitamin C and antioxidant activity. Ujwala x Anugraha was identified as best specific combiner for number of fruits per plant and green yield. The general and specific combining ability revealed that there was preponderance of non-additive gene action for plant height, number of branches, days to flower, days to harvest, days from flowering to harvest, fruit width, fruit girth, average fruit weight, yield per plant, phosphorus, calcium, magnesium, iron and antioxidant activity. Number of fruits per plant, capsaicin, vitamin C and beta carotene were governed by additive gene action. All the hybrids were found resistant to bacterial wilt in the field as well as when inoculated artificially with the pathogen.

Key words: Bacterial wilt resistance, Chilli, General combining ability, Hybrids, Specific combining ability.

INTRODUCTION

Chilli also called as pepper, belongs to the genus *Capsicum* of the solanaceae family, is an important crop grown all over the world. Chillies are integral and the most important ingredient in many different cuisines around the world as it adds pungency, flavor, taste and color to the dishes. India is the major producer and is the leader in export, with 25 per cent share in world trade followed by China. The most important chilli growing states in India are Andhra Pradesh, Maharashstra, Karnataka and Tamil Nadu, which together constitute nearly 75 per cent of the total area (Source: Spice Board, India). Eventhough chilli is cultivated in homesteads of Kerala for green chilli purpose, major share of requirement is met from neighbouring states. The main threat in the cultivation of chilli is bacterial wilt caused by *Ralstonia solanacearum* which is severe in the acidic soils of Kerala. Therefore, any high yielding variety or hybrid developed should have a resistance to bacterial wilt. Gopalakrishnan and Peter (1991) and Markose (1996) developed the bacterial wilt resistant varieties Manjari, Ujwala and Anugraha for Kerala condition. But these varieties were small fruited and highly pungent with less acceptance. The F_1 hybrids from other public and private sector organisations are highly susceptible to bacterial wilt and hence cannot be successfully cultivated in the state. Therefore, it is necessary to incorporate bacterial wilt resistance in high yielding genotype to produce an acceptable F_1 hybrid that can play an important role in the future of chilli production in Kerala. The ever rising importance of chilli production and export, it is necessary to develop high yielding hybrid(s) with high quality for Kerala. Therefore, the project was undertaken to develop bacterial wilt resistant high yielding F hybrid(s) in chilli and also to estimate the combining ability for yield and yield attributes.

MATERIALS AND METHODS

The present research was conducted in the field plots of Department of Olericulture, College of Horticulture, Vellanikkara, in two seasons, from May 2015 to August 2015 and November 2015 to March 2016. Five chilli genotypes *viz,* Ujwala, Anugraha, VKC 2, VKC11and VKC76 were selected as parents for producing hybrids since they were found resistant to bacterial wilt in the field. These parents were crossed in a diallel pattern without reciprocals (half or partial diallel) to produce ten F_1 hybrids. The seeds were collected from the female parents and stored. The parents and the F_1 hybrids were grown in the bacterial wilt sick field for studying the reaction to disease and also its fruit yield and yield attributes. The experiment was laid out in a randomized block design with two replications in a plots of size 3m x 3m with thirty plants per plot. The spacing followed

*Corresponding author's e-mail: nimishasarajames@gmail.com

was 60 between rows and 50 cm between plants. Pusa Jwala was planted in between every plot to confirm the presence of sufficient inoculum of *Ralstonia solanacearum* in field. The cultural operations were done as per the recommendations of the package of practices by Kerala Agricultural University (2011). Observations were recorded on ten randomly tagged plants from parent and hybrid and data were subjected to combining ability (Griffing 1956).

RESULTS AND DISCUSSION

The analysis of variance for combining ability for 19 characters were tested and significant variability was seen among the 15 genotypes experimented (Table.1).General combining ability was significant for all the characters, while variance due -sca effects were significant for plant height, number of branches, days from flowering to harvest, fruit length, fruit width, fruit girth, number of fruits per plant, average fruit weight, fruit yield per plant, phosphorus, calcium, magnesium, iron, vitamin C, antioxidant activity, beta carotene. The gca and sca effects of the parents and F hybrids were estimated and presented in Table 2 and Table 3, respectively.

There was significant gca and sca variances for plant height, number of branches, days from flowering to harvest, fruit length, fruit width, fruit girth, number of fruits per plant, average fruit weight, yield per plant, phosphorus, calcium, magnesium, iron, Vitamin C, antioxidant activity, and beta carotene. Since there is significance for gca and sca variances, the possible role of additive and non-additive gene action in governing these characters is indicated. The gca variance alone was significant for days to flower, days to harvest and capsaicin. However, preponderance of non-additive gene action was observed for plant height, number of branches, days from flowering to harvest, fruit length, fruit width, fruit girth average fruit weight, yield per plant, phosphorus, calcium, magnesium, iron and antioxidant activity. Similar results were obtained by Pandian and Shanmugavelu (1992); Shukla *et al*. (1999); Baruah (2003), Srivastava *et al*. (2004); Reddy *et al*.,2008; and Chaudhary *et al*.(2013). Number of fruits per plant, days to flower, days to harvest, Capsaicin, Vitamin C and Beta carotene had shown addictive gene action in the study. Dhall (2008) also reported preponderance of additive gene action in capsaicin and Vitamin C.

The highest gca effect for plant height was observed in VKC 76 and lowest negative gca was in Anugraha indicating that VKC 76 can improve the plant height. Highest sca was seen in the cross, Anugraha x VKC 76 followed by Ujwala x VKC 2 and VKC 2 x VKC 11. High gca effect was recorded in Ujwala followed by Anugraha for the number of branches indicating that both were good general combiners. Sca effect was the highest in cross Ujwala x VKC 76 followed by Ujwala x VKC 11 and was more than gca effect indicating the role of non additive gene action.

The gca effect was negative for days to flower and days to harvest in VKC 2, VKC 11 and VKC 76. Anugraha also had a negative gca effect in case of days to harvest. Spaldon *et al*. (2015) also reported high negative gca effect for this character. The negative sca effect observed in the hybrids *viz*. Ujwala x Anugraha, Anugraha x VKC 2, Anugraha x VKC 76, VKC 2 x VKC 11, VKC 2 x VKC 76 and VKC 11 x VKC 76 indicated that hybrids involving parents with negative gca effect would give F_1 hybrids which

Table 1: Analysis of variance for combining ability in diallel (5 x 5) cross of chilli

Characters	GCA 4df	SCA 10df	Error 14df
Plant height	794.74*	122.21*	1.67
Number of branches	10.47*	7.91*	0.033
Days to flower	42.04*	11.07	16.86
Days to harvest	100.59	10.37	17.87
Days from flowering to harvest	15.64*	1.83*	0.08
Fruit length	31.55*	3.85*	0.001
Fruit width	1.46*	0.60*	0.004
Fruit girth	7.04*	1.17*	0.008
Number of fruits/plant	10,607.98*	3,918.64*	200.020
Average fruit weight	11.28*	2.54*	0.017
Fruit yield per plant	0.03*	0.03	0.01
Phosphorus	103.71*	38.82*	0.37
Calcium	76.24*	70.82*	0.02
Magnesium	144.71*	91.98*	0.04
Iron	0.34*	0.19*	0.002
Capsaicin	0.006*	0.003*	0.00
Vitamin C	2,183.95*	1,419.07	367.44
Antioxidant activity	48,671.79*	49,149.29*	98.57
Beta carotene	265,699.13*	131,193.19*	455.06

*Significant at 1% level

Table 2: Estimates of gca effect of the five parents geotypes for 19 characters

Characters	Ujwala	Anugraha	VKC 2	VKC 11	VKC 76	S.E. +
Plant height	-0.094	-29.915	-1.204	-6.863	38.08*	0.308
Number of branches	16.56*	15.9*	-1.95	1.295	-31.8	0.044
Days to flower	2.85*	0.299	-0.246	-1.512	-1.38	0.981
Days to harvest	4.535*	-0.193	-0.94	-2.35	-1.049	1.011
Days from flowering to harvest	26.26*	-6.12	-11.18	-12.65	3.712*	0.066
Fruit length	-213.5	-248.5	38.875	166.63*	177.88*	0.008
Fruit width	-4.714	-32.79	4.714	0.928	31.85*	0.014
Fruit girth	-13.19	-33.28	-22.57	20.61*	48.43*	0.021
Number of fruits/plant	6.977*	8.74*	-0.495	-4.415	-11.07	3.381
Average fruit weight	-27.90	-26.13	-1.613	14.7*	40.94*	0.031
Yield per plant	-1.043	2.435*	1.217	-0.30	-2.35	0.023
Phosphorus	18.48*	12.55*	2.15*	-3.28	-29.91	0.145
Calcium	45.45*	70.96*	1.33	-4.27	-113.51	0.033
Magnesium	22.58*	41.72*	33.72*	15.6*	-113.62	0.050
Iron	14*	5.75*	-15.08	7.75*	-12.42	0.012
Capsaicin	-17	13*	29*	-2	-23	0.001
Vitamin C	-1.77	-1.63	-0.976	4.78*	-0.39	4.582
Antioxidant activity	-35.18	9.96*	-12.91	29.98*	8.16*	2.373
Beta carotene	1.09	-23.4	-30.83	27.16*	26.06*	5.099

*Significant at 1% level

takes minimum number of days to flower. Vaishnav *et al*. (2010) also reported similar findings. Days from flowering to harvest had a negative gca effect in Anugraha, VKC 2 and VKC 11. The negative sca effect for number of days from flowering to harvest observed in the hybrids Anugraha x VKC 11, Anugraha x VKC 76 and VKC 11 x VKC 76 was because of the non- additive gene action in controlling the character. Ramesh *et al*. (2013) also reported similar results.

High positive and significant gca effect was observed in VKC 76, VKC 2 and VKC 11 for fruit length, width and girth rated as good general combiner for these characters. The F_1s, Ujwala x VKC 2, Anugraha x VKC 2, Anugraha x VKC 76, had high sca effect for fruit length, fruit width and girth. VKC 11 x VKC 76 had also high sca effect for fruit length. The parents with high gca effect and the crosses with high sca effect can be utilized for obtaining F_1 hybrids having more fruit length, width and girth (Adarsh and Poonam kumari, 2015). Ujwala x VKC 2 and Anugraha x VKC 2 had high sca effect eventhough the parents had negative gca effect for fruit length and girth. It indicated that the character was governed by non-additive gene action. Similar results were observed by Juliemole (2000) in ridge gourd.

Anugraha and Ujwala had high positive and significant gca effect and classified as good general combiners for number of fruits per plant. Preponderance of non-additive gene action was indicated in Ujwala x Anugraha and Anugraha x VKC 11 due to high sca effect for this trait.

VKC 76 and VKC 11were good general combiners for average fruit weight. Positive and significant sca effect for Ujwala x VKC 76, VKC11 x VKC 76, Anugraha x VKC 76, VKC 2 x VKC 11, Anugraha x VKC 2 and Ujwala x VKC 2 indicated that these crosses could be used in developing hybrids with high average fruit weight.

Anugraha was the only parent which had positive and significant gca effect for fruit yield per plant and it was reflected in the positive and significant sca effect in Ujwala x Anugraha. However, the *per se* performance showed that Ujwala x VKC 11 was the best among F_1 hybrids. Eventhough the sca effect of this cross was minimum and negative it was higher than the gca effect of the parents Ujwala and VKC 11 indicating that the yield per plant was controlled by non-additive gene action.

The gca effect was positive and significant in Ujwala and Anugraha for phosphorus and calcium content in green fruits. Ujwala x Anugraha had maximum sca effect for phosphorus and calcium content. The sca effect of Ujwala x Anugraha was higher than gca effect and thus character was governed by the non-additive gene action. High positive and significant value for gca effect was observed in Anugraha, Ujwala and VKC 11 for magnesium and iron content. VKC 2 is also a good general combiner for magnesium content. Ujwala x Anugraha and Ujwala x VKC 11 had the maximum sca effect for magnesium and iron content, respectively.

VKC 2 and Anugraha were found to be good combiners for capsaicin content. Anugraha x VKC 11 showed maximum positive and significant sca effect. Since the gca effect was found to be more than the sca effects the character might be controlled by additive gene action. Singh and Hundal (2001) also got similar results.

Highest positive and significant gca effect was recorded in VKC 11 followed by VKC 76 for vitamin C, antioxidant activity and beta carotene. Ujwala x VKC 11 had the highest positive and significant sca effect for Vitamin C and antioxidant activity. But the gca effect of VKC 11 was more than the sca effect of Ujwala x VKC 11 in case of vitamin C indicating the additive gene action (Geleta *et al*., 2006) and vice versa in case of antioxidant activity indicating the non-additive gene action.

Table 3. Estimate of sca effect in the F hybrids in all the 19 characters

Hybrids	**Plant height**	**Number of branches**	**Days to flower**	**Days to harvest**	**Days from F to H**	**Fruit length**	**Fruit width**	**Fruit girth**	**No.of fruits per plant**	**Average fruit weight**
Ujwala x Anugraha	-1.33	-85.5	-0.25	0.09	4.67*	3.86*	-10.57	-13.81	6.96*	-8.09
Ujwala x VKC 2	14.198*	0.55	0.15	0.38	3.57*	102.71*	6.598	22.13*	-5.29	4*
Ujwala x VKC11	6.71*	42.75*	0.37	0.69	4.73*	83.57*	0.34	4.45*	-2.56	-2.80
Ujwala x VKC 76	3.89*	44.59*	1.43	1.43	1.02	-102.62	35.248	22.86*	-7.15	23.95*
Anugraha x VKC 2	-11.19	-32.9	-1.58	-1.11	5.84*	30.81*	-1.57	11.98*	-4.80	17.08*
Anugraha x VKC 11	-0.59	-22.95	0.96	0.59	-0.99	-78.80	7.67*	5.26*	5.99*	-6.82
Anugraha x VKC 76	16.06*	42.448	-0.03	-0.09	-1.41	29.76*	4.65*	3.11*	-0.68	3.52*
VKC 2 x VKC 11	6.64*	29.65*	-0.45	0.02	6.33*	-34.29	-1.22	-4.56	-0.04	3.43*
VKC 2 x VKC 76	-6.98	14.81*	-0.43	-0.82	-5.91	-31.43	-17.22	-16.33	4.35*	-7.59
VKC 11 x VKC 76	-0.02	-38.40	-0.38	-0.31	3.19*	19.678	-2.84	-3.72	-0.19	17.72*
S.E. ±	0.79	0.11	2.53	2.61	0.17	0.02	0.04	0.05	8.73	0.08

Hybrids	Yield /Plant	Phosphorus	Calcium	Magnesium	Iron	capsaicin	Vitamin C	Antioxidant activity	Betacarotene
Ujwala x Anugraha	3.8*	24.93*	179.36*	136.58*	4.6*	-13	-0.93	-6.47	2.79*
Ujwala x VKC 2	-1.38	-8.42	-65.5	-30.76	-8.2	4.338	1.39	24.82*	21.44*
Ujwala x VKC11	-0.18	-7.48	-15.68	-20.68	25.47*	-5	3.77*	44.12*	-5.80
Ujwala x VKC 76	-2.2	0.49	-60.02	-22.98	-4.47	-19	0.49	1.17	-10.69
Anugraha x VKC 2	-0.8	13.98*	-5.81	18.39*	3.13*	-14	0.66	-9.79	-3.83
Anugraha x VKC 11	1.97	-6.88	-59.68	-43.55	-3.8	9.67*	-3.43	-34.96	-22.49
Anugraha x VKC 76	0.87	0.37	-24.44	-2.76	-8.6	-2	-1.25	23.25*	-11.70
VKC 2 x VKC 11	0.37	5.19*	24.33*	28.28*	-1.7	4.67*	-0.98	0.41	-30.95
VKC 2 x VKC 76	2.1	3.07*	34.51*	7.20*	0.13	-11.67	1.49	16.61*	-4.9
VKC 11 x VKC 76	0.4	-0.68	-3.91	1.62	-3.67	4.67*	-1.41	-8.98	-1.23
S.E. ±	0.06	0.37	0.08	0.13	0.03	0.003	11.83	6.13	13.17

*Significant at 1% level

Evaluation of hybrids and parents for bacterial wilt incidence: Two parents, (VKC 2 and VKC 11) were resistant to bacterial wilt, also shown some incidence of bacterial wilt (below 20%). Thus both were considered as resistant parents. The F_1 hybrids shown 100% resistance to bacterial wilt except in cross, Ujwala x VKC 11. The per cent of incidence was an average of 12% for parents and hybrids. Since it was less than 20% they were also considered as resistant. This resistance showed by hybrids may be due to the dominant action of the resistance gene. Dominant action of gene involved in resistance was also reported by Sood and Kumar (2013). All the Pusa Jwala seedlings planted were attacked by pathogen before flowering, confirmed the presence enough of inoculum load in the field. All the hybrids were found to be resistant in field and also when inoculated artificially with pathogen by leaf axil puncturing and soil drenching.

When the morphological characters were studied there was inheritance of light green fruit colour of Anugraha in its hybrids. Like-wise, fruit orientation at an angle between erect and pendent was observed in case of Ujwala x Anugraha.

Ujwala was observed as the good general combiner for number of branches, days to flower, days to harvest, days from flowering to harvest, number of fruits per plant, phosphorus, calcium, magnesium and iron in chilli. Likewise, for plant height, fruit length, fruit width, fruit girth, average fruit weight and beta carotene VKC 76 was the good general combiner. Anugraha had high gca effect for number of branches, number of fruits per plant, yield per plant, phosphorus, calcium, magnesium, iron and beta carotene. VKC 11 showed high gca effect for fruit length, fruit girth magnesium, iron, vitamin C and beta carotene. VKC 2 was the good general combiner for fruit length, fruit width and iron.

Highest sca effects were observed for plant height(16.06) in Anugraha x VKC 76, number of branches (44.59) in Ujwala x VKC 76, fruit length and beta carotene (21.44) in Ujwala x VKC 2 (102.71), average fruit weight (23.95) and fruit width (35.24) and girth (22.86) in Ujwala x VKC 76, number of fruits per plant (6.96), fruit yield per plant (3.8), phosphorus (24.93), calcium (179.36), magnesium (136.58) in Ujwala x Anugraha, iron (25.47), vitamin C (3.77) and antioxidant activity (44.12) in Ujwala x VKC 11, capsaicin (9.67) in Anugraha x VKC 11.

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