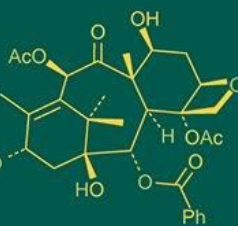
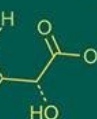


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Akumla Longchar
AICRP on Kharif Pulses,
Medziphema Nagaland
University, Nagaland, India

Alisha Dwibedy
Ph.D. Research Scholar,
Odisha University of
Agriculture and Technology,
Bhubaneswar, Odisha, India

Abhishek Gautam
M.Sc., Department of Seed
Science and Technology,
Chandrasekhar Azad
University of Agriculture and
Technology, Kanpur, Uttar
Pradesh, India

Lalu Prasad
Ph.D., Department of
Vegetable Science, Acharya
Narendra Deva University of
Agriculture and Technology,
Kumarganj, Ayodhya, Uttar
Pradesh, India

Corresponding Author:
Alisha Dwibedy
Ph.D. Research Scholar,
Odisha University of
Agriculture and Technology,
Bhubaneswar, Odisha, India

Studies on the general and specific combining ability effects of the parents and crosses in Pigeonpea

Akumla Longchar, Alisha Dwibedy, Abhishek Gautam and Lalu Prasad

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Abstract

The present investigation was carried out to obtain the information based on the general and specific combining ability effects of the parents and crosses in Pigeonpea. The experiment took two crop seasons viz. *Kharif* 2014-15 and *Kharif* 2015-16. During the *kharif* season of 2014-2015, 12 parental lines i.e. 7 lines and 5 testers were sown in a Randomized Block Design (R.B.D.) with three replications to obtain data on eleven different traits for yield and yield attributes. Simultaneously. The parents B1-141-1, B3-13 among lines and ICP7035 and BRG3 among testers proved to be good combiners for green pod yield / plant. Also, the line B3-13 and B1-141-1 proved to be the best combiner for secondary, number of pods / plant and number of pods / clusters. B1-141-1 proved to be the best combiner for primary branches, secondary branches, number of pods / plant and green pod yield / plant and the cross BRG2 x BRG3 exhibited the highest sca effects for plant height, days to 50% flowering, primary branches, secondary branches, number of pods / plants, green pod yield / plant and second highest sca effects for number of pods / cluster and number of seeds / pods. It also exhibited second highest value of heterobeltiosis and relative heterosis for primary branches, secondary branches, number of pods / plant and green pod yield / plant.

Keywords: Good combiners, heterobeltiosis, pods/cluster

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp], ($2n=2x=22$) also known as arhar, tur and red gram, is nutritionally balanced and an exceptional source of protein in both green pea and dried grain (Faris and Singh, 1990) [13]. Along with protein, pigeonpea also renders carbohydrates and Vitamin A and C (Faris *et al.* 1987) [14]. Pigeonpea seeds are rich in proteins (generally within a range of 18 to 25% and as high as 32%), carbohydrates (57.6%), fiber (1.5%), minerals (3.5%), amino acids, methionine and cystine (Birk, 1993) [8]. Because of its rich source of protein, it is an ultimate addition to traditional cereal, banana or tuber-based diets of poor farmers that are protein deficient. Its ability to produce economic yield under limited moisture condition makes it an important crop of dryland agriculture.

Globally the area and production of pigeonpea has increased from 2.86 million ha and 1.96 million tons in 1980 to 4.36 million ha and 3.46 million tons in 2006, respectively (FAO Stat, 2008) [10]. Pigeonpea represents about 5% of world legume production and more than 70% is being produced in India.

Pigeonpea is the second most important pulse crop of India which accounts for 20 percent of the total pulse production in India. In India, pigeonpea is grown in an area around 4.04 million hectare with a production of approximately 2.65 million tons (Anonymous, 2012) [12]. It has registered a production of 4.02 million tons in the year 2017-18 (All India Coordinated Research Project on Pigeonpea, Annual Report 2017-18). As 'dal', pigeonpea is an important constituent of the Indian meal. Of the total pigeonpea production in the world, India alone contributes nearly 92 per cent of it.

In India average productivity of pigeonpea is lower (671 kg/ha) compared to the world average productivity (742 kg/ha) even though it leads the world in area and production (FAOSTAT, 2010) [12]. Production of pigeonpea in India is still short which cannot fulfil the present consumption of ~19 million tonnes thereby compelling to import pulses to a range of 1.5-2.0 million tons annually (<https://www.agricoop.nic.in>, accessed on Feb. 28, 2013). WHO recommendation of per capita availability of protein is 80 g/day (Saroj *et al.*, 2013), while it is only 28 g/day in India which does the ultimate problem of the malnutrition exist

among the poor people. The chasm between per capita availability of protein in India and WHO recommendation can be bridge through pulses which is a rich source of protein.

The importance of pulses in Indian agriculture cannot be denied. Of the total pulses, red gram or pigeonpea takes an important place among rainfed resource poor farmers as it provides quality food, fertilizer, fuel wood and fodder. Despite its immense importance in sustainable agriculture its global production per hectare has remained static over last three decades. Lack of efficient management practices coupled with biotic and abiotic stresses has widened the gap between the potential yield and on-farm yield.

The conventional breeding procedures followed in pigeon pea brought improvement in seed yield and resistance to diseases and pests. However, for further boost in productivity, the possibility of producing pigeon pea hybrids and identification of superior hybrids through line x tester mating design open up new avenues.

The study of heterosis and combining ability helps plant breeders in choosing suitable parents and also helps in understanding the magnitude of gene action involved in the inheritance of quantitative traits of economic importance. Accordingly, the present investigation "Combining ability analysis for vegetable yield and its components in pigeonpea [*Cajanus cajan* (L.) Millsp.]" was undertaken to have the knowledge on nature of combining ability and heterosis for yield and yield attributes in pigeon pea.

Materials and Methods

The experiment entitled "Combining ability analysis for vegetable yield and its components in pigeonpea [*Cajanus cajan* (L.) Millsp.]" was carried out during *kharif* seasons in 2014-15 and 2015-16 at the experimental farm of Department of Genetics and Plant Breeding, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema campus, which is located at 23° 45' 49" N latitude, 90° 33' 04" E longitude at an altitude of 305 m above sea level bearing sub-tropical climate and the experiment took two crop seasons *viz.* *Kharif* 2014-15 and *Kharif* 2015-16. During the *kharif* season of 2014-2015, 12 parental lines i.e. 7 lines and 5 testers were sown in a Randomized Block Design (R.B.D.) with three replications to obtain data on eleven different traits for yield and yield attributes. Simultaneously, the five tester and seven parental lines were grown during *kharif* 2014-15 in a crossing plot. F₁ hybrids were produced following Line X Tester mating system involving 7 lines and 5 testers by hand emasculation and pollination technique. In the next crop season i.e., *Kharif* 2015-16, all the seeds of 35 F₁ cross combinations (7 lines x 5 testers) with the 12 parental lines (7 lines and 5 testers) totalling 47 treatments were grown in a Randomized Block Design (RBD) with three replications.

Combining ability analysis

The experimental data obtained on each character were subjected to the analysis of variance (Gomez and Gomez, 1984) [15]. After testing the significance of treatment i.e. genotypes including parents and crosses, line x tester analysis for estimation of combining ability was done.

Result and Discussion

Choosing the right parents and using the right breeding techniques are fundamental steps in transferring traits. The

parents chosen for the crossing program were assessed according to their gene action in creating superior hybrids. Below is a discussion of various field attributes results

Plant height

The combining ability effects for plant height are presented in Table 4.7.1. The sca effects ranged from -107.94 to 148.28. The maximum sca effects was observed in the cross BRG-2 X BRG-3. (Anithavasline, Y., Suguna, V and Padmavathi, S. 2007) [1]. Table. 1

The gca values of lines and testers ranged from -93.66 to 41.33 and -20.58 to 14.77 respectively. The maximum value of gca in lines and testers were observed in B2-10 and B1-169-1.

Days to 50% flowering

The combining ability effect for Days to 50% flowering is presented in Table 4.7.2. The sca effects ranged from -13.47 to 17.53. The maximum sca effects was observed in the cross BRG2 X BRG3. (Arbad, S. K. Madrap, I. A. Jadhav, P. 2013) [3]. Table. 2

The gca for lines and testers ranged from -4.64 to 8.56 and -3.63 to 2.56, respectively. The maximum value of gca lines and testers were observed in B2-5-2-1 and ICP7035.

Primary branches per plant

The combining ability effects for primary branches is presented in Table 4.7.3. The sca effects ranged from -18.12 to 35.39. The maximum sca effects was observed in the cross BRG2 X BRG3. (Banu, M. R.; Muthaiah, A.R. and Ashok, S. 2006) [4]. Table. 3

The gca lines and testers ranged from -13.45 to 8.73 and -1.45 to 3.49 respectively. The maximum value of gca lines and testers were observed in B1-414-1 and ICP7035, respectively.

Secondary branches per plant

The combining ability effect for secondary branches is presented in Table 4.7.4. The sca effects ranged from -145.59 to 301.09. The maximum sca effects was observed in the cross BRG2 X BRG3. (Barad, H.R., Pithia, M.S and Vachhani, J.H. 2008) [5]. Table. 4

The gca lines and testers ranged from -51.02 to 47.68 and -35.42 to 53.51, respectively. The maximum value of gca lines and testers was observed in B3-13 and ICP7035.

Number of pods per cluster

The combining ability effects for Pods/cluster are presented in Table 4.7.5. The sca effects ranged from -0.86 to 1.01. (Baskaran, K. and Muthian, A. R. 2007) [6]. Table. 5

The maximum positive significant sca effects was recorded in the cross between B1-66-1 X ICP7035. The gca (lines) and gca (testers) ranged from -0.71 to 0.62 and -0.34 to 0.32, respectively and maximum value was recorded in B3-13 and ICP7035.

Number of pods per plant

The combining ability effects for pods/plant are presented in Table 4.7.6. The sca effects ranged from -107.72 to 212.82 (Bhavani, N.L. and Bhalla, J.K. 2010) [7]. Table. 6

The maximum positive significant sca effects was recorded in the cross between BRG 2 X BRG 3. The gca (lines) and gca (testers) ranged from -41.92 to 50.81 and -28.47 to 51.47, respectively and maximum was recorded in B3-13

and ICP7035.

Number of seeds per pod

The combining ability effects for seeds/pod are presented in Table 4.7.7. The sca effects ranged from -0.66 to 0.91. (Chaudhari, K.N., Chauhan, R.M. and Prajapati, B.H. 2004) [9] Table. 7

The maximum positive significant sca effects was recorded in the cross between B1-51 X ICP7035. The gca (lines) and gca (testers) ranged from -0.69 to 0.38 and -0.41 to 0.35, respectively and maximum was recorded in B1-141-1 and ICP7035.

100 Seed weight

The combining ability effects for 100 seed weight are presented in Table 4.7.8. The sca effects ranged from -2.36

to 2.76. (Gupta DK, Acharya S and Patel JB 2011) [16] Table. 8.

The maximum positive significant sca effects was recorded in the cross between B1-51 X ICP7035. The gca (lines) and gca (testers) ranged from -0.94 to 0.69 and -0.82 to 0.65, respectively and maximum was recorded in B1-66-1 and B2-106-1.

Green pod yield per plant

The combining ability effects for green pod yield/ plant are presented in Table 4.7.9. The sca effects ranged from -282.22 to 567.27. (Jahagirdar, J. E. 2003) [17] Table.9

The maximum positive significant sca effects were recorded in the cross between BRG2 X BRG3. The gca (lines) and gca (testers) ranged from -102.99 to 120.79 and -86.81 to 130.27, respectively and maximum were recorded in B1-141-1 and ICP7035.

Table 1: Combining ability effects for plant height

Lines		Testers					
		BRG1	BRG3	B1-169-1	B2-106-1	ICP-7035	gca (lines)
1	B1-66-1	23.40	-23.37	-0.91	-1.38	2.26	6.32
2	B3-13	9.14	1.55	-21.27	7.30	3.28	25.24*
3	B2-5-2-1	17.85	4.07	7.85	14.69	-44.46*	28.45**
4	B1-141-1	26.82	-10.75	-21.59	-11.24	16.76	25.76
5	B1-51	-37.84	-107.94**	11.14	47.69*	86.96**	-33.44**
6	BRG-2	-37.62	148.28**	-2.97	-55.87*	-51.82*	-93.66**
7	B2-10	-1.75	-11.85	27.77	-1.19	-12.97	41.33**
	gca (testers)	-20.58*	-0.48	14.77	-1.33	7.62	

	gca (L)	gca (T)	sca	gi - gj (L)	gi - gj (T)	Sij - Skl
S.E.	9.77	8.25	21.84	13.81	11.67	30.89
C.D. (5%)	19.49	16.47	43.58	27.56	23.29	61.63
C.D. (1%)	25.88	21.87	57.88	36.60	30.94	81.84

Table 2: Combining ability effects for days to 50% flowering

Lines		Testers					
		BRG1	BRG3	B1-169-1	B2-106-1	ICP-7035	gca (lines)
1	B1-66-1	-4.76*	0.33	1.19	2.81	0.43	-2.57**
2	B3-13	-2.29	-1.20	0.66	1.28	1.56	-4.37**
3	B2-5-2-1	-4.36*	-0.93	0.92	1.21	3.16	-4.64**
4	B1-141-1	5.57**	-1.33	0.52	0.81	-5.57**	-2.24**
5	B1-51	8.44**	17.53**	-8.28**	-10.32**	-7.37**	8.56**
6	BRG-2	-1.56	-13.47**	6.72**	4.68*	3.63	8.56**
7	B2-10	-1.03	0.93	-1.74	-0.46	4.16*	-3.31**
	gca (testers)	2.56**	1.47*	-0.72	0.32	-3.63**	
		gca (L)	gca (T)	sca	gi - gi (L)	gi - gi (T)	Sij - S _{kl}
S.E.		0.82	0.69	1.83	1.16	0.98	2.59
C.D. (5%)		1.63	1.38	3.65	2.31	1.95	5.16
C.D. (1%)		2.17	1.83	4.85	3.06	2.59	6.86

Table 3: Combining ability effects for primary branches per plant

Lines		Testers					
		BRG1	BRG3	B1-169-1	B2-106-1	ICP-7035	gca (lines)
1	B1-66-1	2.98	-9.88	4.20	4.03	-1.33	-6.67
2	B3-13	-4.17	2.48	0.21	-2.55	4.02	6.51
3	B2-5-2-1	4.14	-0.48	1.26	1.89	-6.81	2.34
4	B1-141-1	30.49**	-7.74	-9.79	-6.07	-6.87	8.73*
5	B1-51	-14.89	-18.12*	2.23	9.49	21.29*	-5.43
6	BRG-2	-11.88	35.91**	-3.75	-10.59	-9.69	-13.45**
7	B2-10	-6.66	-2.17	5.64	3.80	-0.62	7.96*
	gca (testers)	-1.32	-0.11	-1.45	-0.61	3.49	
gca (L)		gca (T)	sca	gi - gj (L)	gi - gj (T)		Sij - Skl
S.E.		3.62	3.06	8.10	5.12	4.33	11.46
C.D. (5%)		7.23	6.11	16.17	10.23	8.64	22.87
C.D. (1%)		9.60	8.12	21.47	13.58	11.48	30.37

Table 4: Combining ability effects for secondary branches per plant

Lines		Testers					
		BRG1	BRG3	B1-169-1	B2-106-1	ICP-7035	gca (lines)
1	B1-66-1	59.70	-61.17	22.64	9.40	-30.57	-51.02**
2	B3-13	-45.53	-29.61	15.97	-33.05	92.21*	47.68**
3	B2-5-2-1	88.91*	-26.57	23.09	24.40	-109.83**	12.85
4	B1-141-1	5.15	-9.45	-16.27	0.23	20.35	32.87
5	B1-51	-85.26*	-145.59**	-20.94	72.97	178.81**	-8.60
6	BRG-2	-49.58	301.09**	-46.59	-71.41	-133.51**	-49.28**
7	B2-10	26.60	-28.72	22.10	-2.52	-17.46	15.50
	gca (testers)	-35.42*	22.91	-27.41	-13.59	53.51**	
		gca (L)	gca (T)	sca	gi - gj (L)	gi - gj (T)	Sij - Skl
S.E.		16.78	14.18	37.52	23.73	20.06	53.06
C.D. (5%)		33.48	28.29	74.87	47.35	40.02	105.89
C.D. (1%)		44.47	37.58	99.44	62.89	53.15	140.62

Table 5: Combining ability effects for number of pods per cluster

Lines		Testers					
		BRG1	BRG3	B1-169-1	B2-106-1	ICP-7035	gca (lines)
1	B1-66-1	0.34	-0.61*	-0.28	-0.47	1.01**	-0.25
2	B3-13	0.14	-0.48	0.52	-0.33	0.14	0.62**
3	B2-5-2-1	-0.12	0.26	0.59	0.07	-0.79*	0.55**
4	B1-141-1	-0.52	-0.14	-0.48	0.33	0.81**	-0.05
5	B1-51	-0.12	-0.41	-0.41	0.73*	0.21	-0.45
6	BRG-2	0.14	0.86**	-0.14	-0.33	-0.52	-0.71**
7	B2-10	0.14	0.52	0.19	0.00	-0.86**	0.29*
	gca (testers)	-0.34**	-0.06	-0.06	0.13	0.32**	
		gca (L)	gca (T)	sca	gi - gj (L)	gi - gj (T)	Sij - Skl
S.E.		0.13	0.11	0.30	0.19	0.16	0.42
C.D. (5%)		0.27	0.23	0.59	0.38	0.32	0.85
C.D. (1%)		0.36	0.30	0.79	0.50	0.43	1.13

Table 6: Combining ability effects for number of pods per plant

Lines		Testers					
		BRG1	BRG3	B1-169-1	B2-106-1	ICP-7035	gca (lines)
1	B1-66-1	11.99	-57.24	-2.45	-9.25	56.94	-37.62*
2	B3-13	129.07**	-54.28	-13.11	-37.05	-24.63	50.81**
3	B2-5-2-1	43.90	-26.02	51.83	38.02	-107.72**	12.64
4	B1-141-1	-79.18*	-39.35	-36.65	-13.76	168.93**	40.59*
5	B1-51	-34.21	-54.61	-32.32	56.69	64.44	-41.92*
6	BRG-2	-44.11	212.82**	-31.39	-30.19	-107.13**	-35.68*
7	B2-10	-27.48	18.67	64.08	-4.45	-50.83	11.18
	gca (testers)	-14.23	7.18	-15.95	-28.47	51.47**	
		gca (L)	gca (T)	sca	gi - gj (L)	gi - gj (T)	Sij - Skl
S.E.		17.19	14.52	38.43	24.30	20.54	54.35
C.D. (5%)		34.29	28.98	76.68	48.49	40.99	108.45
C.D. (1%)		45.54	38.49	101.84	64.41	54.43	144.02

Table 7: Combining ability effects for number of seeds per pod

Lines		Testers					
		BRG1	BRG3	B1-169-1	B2-106-1	ICP-7035	gca (lines)
1	B1-66-1	0.01	0.01	-0.18	-0.09	0.25	0.18
2	B3-13	-0.19	0.14	0.29	0.05	-0.29	0.05
3	B2-5-2-1	0.21	-0.12	0.35	0.11	-0.55*	-0.02
4	B1-141-1	0.14	-0.19	-0.38	0.05	0.38	0.38**
5	B1-51	-0.32	-0.66**	-0.18	0.25	0.91**	-0.15
6	BRG-2	0.21	0.88**	-0.13	-0.22	-0.55*	-0.69**
7	B2-10	-0.06	-0.06	0.42	-0.15	-0.15	0.25*
	gca (testers)	-0.41**	-0.08	0.11	0.02	0.35**	
		gca (L)	gca (T)	sca	gi - gj (L)	gi - gj (T)	Sij - Skl
S.E.		0.11	0.09	0.24	0.15	0.13	0.34
C.D. (5%)		0.21	0.18	0.47	0.29	0.25	0.67
C.D. (1%)		0.28	0.24	0.63	0.39	0.34	0.89

Table 8: Combining ability effects for 100 seed (green) weight

Lines		Testers					
		BRG1	BRG3	B1-169-1	B2-106-1	ICP-7035	gca (lines)
1	B1-66-1	0.23	0.89	0.91	-0.14	-1.89*	0.69
2	B3-13	0.99	0.78	-2.27*	1.22	-0.72	0.09
3	B2-5-2-1	0.26	-1.25	0.56	0.85	-0.42	-0.14
4	B1-141-1	-0.83	1.22	-0.96	-0.61	1.18	0.23
5	B1-51	-0.39	-2.36*	0.21	-0.21	2.76**	0.61
6	BRG-2	0.54	1.20	-0.52	-0.43	-0.79	-0.94*
7	B2-10	-0.81	-0.48	2.09*	-0.69	-0.10	-0.55
	gca (testers)	0.32	0.21	-0.36	0.65	-0.82*	

	gca (L)	gca (T)	sca	gi - gj (L)	gi - gj (T)	Sij - Skl
S.E.	0.41	0.35	0.92	0.58	0.49	1.30
C.D. (5%)	0.82	0.69	1.84	1.16	0.98	2.60
C.D. (1%)	1.09	0.92	2.45	1.55	1.31	3.46

Table 9: Combining ability effects for green pod yield per plant

Lines		Testers					
		BRG1	BRG3	B1-169-1	B2-106-1	ICP-7035	gca (lines)
1	B1-66-1	25.19	-174.80*	31.33	-29.87	148.15	-93.33*
2	B3-13	349.35**	-97.79	-48.01	-88.77	-114.67	85.36*
3	B2-5-2-1	138.69	-63.49	87.92	113.48	-276.59**	51.76
4	B1-141-1	-214.04*	-113.48	-103.47	-40.81	471.79**	120.79**
5	B1-51	-99.19	-166.54	-43.22	139.38	169.57*	-102.99**
6	BRG-2	-135.77	567.27**	-56.09	-93.18	-282.22**	-82.56*
7	B2-10	-64.12	48.84	131.53	-0.22	-116.03	20.97
	gca (testers)	-26.09	47.51	-86.81**	-64.88*	130.27**	

	gca (L)	gca (T)	sca	gi - gj (L)	gi - gj (T)	Sij - Skl
S.E.	37.41	31.61	83.64	52.90	44.71	118.29
C.D. (5%)	74.64	63.09	166.91	105.56	89.22	236.04
C.D. (1%)	99.13	83.78	221.66	140.19	118.48	313.48

Conclusion

B3-13, B1-141-1 among lines and ICP7035 and BRG3 among testers were proved to be good general combiners for green pod yield / plant and early flowering. The genotypes with high gca effects may provide a base for developing the desired lines for the concerned trait.

High specific combining ability (sca) among the hybridizing parents is due to existence of dominance and interaction effects. Thirteen crosses of the total 35 crosses signify positive sca effects for green pod yield /plant. The best sca effects was observed in the cross, BRG2 x BRG3 for green pod yield /plant which also showed best sca effect for plant height, days to 50% flowering, primary branches, secondary branches, number of pods /plant and green pod yield /plant.

The author's input

Each of the aforementioned authors has contributed significantly both directly and intellectually, and they have all approved the work's publication.

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None

Available data

The datasets used and/or examined in this investigation are available upon reasonable request from the corresponding author.

Statement of ethics

The work was approved by the Department of Genetics and Plant Breeding, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema campus

Informed agreement

The subjects provided written informed consent prior to being enrolled in the study.

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