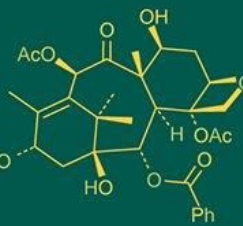
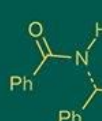


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Akumla Longchar
AICRP on Kharif Pulses,
Medziphema Nagaland
University, Nagaland, India

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

Kavi Sumi
AICRP on Kharif Pulses,
Medziphema Nagaland
University, Nagaland, India

Lowrence Kithan
AICRP on Kharif Pulses,
Medziphema Nagaland
University, Nagaland, India

Rokozeno
AICRP on Kharif Pulses,
Medziphema Nagaland
University, Nagaland, India

Corresponding Author:
Akumla Longchar
AICRP on Kharif Pulses,
Medziphema Nagaland
University, Nagaland, India

Studies on the extent of heterosis in the intervarietal crosses of Pigeonpea

Akumla Longchar, Alisha Dwibedy, Kavi Sumi, Lowrence Kithan and Rokozeno

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Abstract

The present investigation was carried out to obtain the information based on the extent of heterosis in the intervarietal crosses of 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 Among the 35 crosses, six of the hybrids exhibited significant positive heterobeltiosis for green pod yield per plant. The maximum significant positive heterobeltiosis was recorded in the cross B1-141-1 x ICP7035 followed by the cross BRG2 x BRG3. It also manifested high significant heterobeltiosis and relative heterosis for the characters 100 seed weight, number of seeds/pods, number of pods/ plants, secondary branches and primary branches suggesting the possibility of utilizing F₁ and further segregating generations in pigeonpea improvement programme.

Keywords: Heterosis, heterobeltiosis, extent, intervarietal, pigeonpea

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) ^[11]. Along with protein, pigeonpea also renders carbohydrates and Vitamin A and C (Faris *et al.* 1987) ^[10]. 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) ^[15]. 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 have 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) ^[14]. 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 hectares with a production of approximately 2.65 million tons (Anonymous, 2012). 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, 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.

Estimation of heterosis: Data on a variety of quantitative and fruit quality characteristics were used to examine the degree of heterosis. Using the approach recommended by Hayes *et al.* (1955), heterosis was expressed as a percentage increase or decrease in the mean values of F₁s (hybrid) over better-parent (heterobeltiosis) and standard variety (standard heterosis). The following formulas are used to estimate heterosis:

$$(a) \text{ Heterobeltiosis (\%)} = \frac{\bar{F}_1 - \bar{BP}}{\bar{BP}} \times 100$$

$$(b) \text{ Standard heterosis (\%)} = \frac{\bar{F}_1 - \bar{SV}}{\bar{SV}} \times 100$$

Whereas,

$\bar{F}_1$ = Mean value of F₁

$\bar{BP}$ = Mean value of better parent

$\bar{SV}$ = Mean value of standard variety

The significance of heterosis was tested by 't' test as given below:

$$'t' \text{ (Heterobeltiosis)} = \frac{\bar{F}_1 - \bar{BP}}{SE}$$

$$'t' \text{ (Standard heterosis)} = \frac{\bar{F}_1 - \bar{SV}}{SE}$$

$$SE \text{ of heterosis over better-parent and standard variety} = \sqrt{\frac{Me}{r}}$$

Where,

Me = Error mean of square

r = Number of replications

SE = The standard error of the treatments means and (t) is the table value of (t) at 5% or 1% level of significance at error of degree of freedom.

The calculated 't' value was compared with table value 't' at error d.f. at 5% and 1% level of probability for testing the significance of heterosis.

Results 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

Heterosis over the mid parent and better parent for plant height, along with their means and ranges are presented in Table 4.5.1. The extent of heterosis over mid parent ranged from -63.69 (BRG-2 X B2-106-1) to 19.08 (B1-51 X ICP7035). The extent of heterosis over better parent ranged from -63.69 (BRG-2 X B2-106-1) to 9.70 (B1-51 X ICP7035). Significant negative heterosis over the mid parent and better parent was observed for crosses B1-66-1 X BRG3, B1-141-1 X BRG3, B1-51 X BRG1, B1-51 X BRG3, BRG2 X BRG1, BRG2 X B1-169-1, BRG2 X B2-106-1 and BRG2 X ICP7035. (Patel, G.V. Zaveri, P.P. and Pathak A.R. 1991)^[9]. Table.1

Days to 50% flowering

Heterosis over the mid parent and better parent for days to 50% flowering, along with their means and ranges were presented in Table 4.5.2. The cross B1-141-1 X ICP7035 showed significant negative heterosis over better parent. The maximum negative mid parent heterosis of 1.45 percent were recorded from the cross B1-141-1 X ICP7035. (Patel, J.A. and Patel, D.B. 1992)^[8] Table 2.

Primary branches per plant

Heterosis over the mid parent and better parent for primary branches, along with their means and ranges is presented in Table 4.5.3. Among the 35 crosses, the cross B1-141-1 X BRG-1 exhibited maximum significant positive heterosis of 199.12 and 225.09 over better parent and mid parent respectively. The maximum negative mid parent and better parent heterosis of -80.88 and -81.78 were recorded from

the cross BRG-2 X BRG-1. (Phad, D.S.; Madrap, I.A. and Dalvi, V.A 2009) ^[7] Table 3.

Secondary branches per plant

Heterosis over the mid parent and better parent for secondary branches, along with their means and ranges are presented in Table 4.5.4. The maximum significant mid parent heterosis of 140.92 and better parent heterosis of 126.06 were observed in the cross B1-51 X ICP7035 followed by BRG2 X BRG3. Maximum significant negative mid parent heterosis of -92.28 and better parent of -92.39 were recorded in the cross BRG-2 X B2-106-1. (Priyankavyas., Vishwakarma, D.N and Singh, P.K. 2008) ^[6] Table 4.

Number of pods per cluster

Heterosis for number of pods/clusters over better parent and mid parent along with their respective means and ranges are presented in Table 4.5.5. The extent of heterosis for number of pods/clusters over mid parent ranged from -53.85 (B1-51 X BRG-1 and BRG-2 X ICP7035) to 50.00 (B2-5-2-1 X B1-169-1). The extent of heterosis over better parent ranged from -70.00 (BRG-2 X ICP7035) to 33.33 (B2-5-2-1 X B1-106-1). Most crosses exhibited significant negative heterosis while significant positive mid parent values were observed for the crosses B3-13 X BRG, B2-5-2-1 X B1-169-1 and B2-5-2-1 X B2-106-1. (Raju, P.A and Muthiah, A.R 2007) ^[5] Table 5.

Number of pods per plant

Heterosis for number of pods/plant over better parent and mid parent along with their respective means and ranges are

presented in Table 4.5.6. The maximum significant mid parent (196.15) and better parent (179.32) heterosis were recorded from the cross B1-141-1 X ICP7035. (Sathya, M and Jayamani, P. 2011) ^[4] Table 6.

Number of seeds per pod

Heterosis for number of seeds/pod over better parent and mid parent along with their respective means and ranges are presented in Table 4.5.7. The maximum significant mid parent (20.00) and better parent (20.00) heterosis were recorded from the crosses B1-141-1 X ICP7035 and B1-51 X ICP7035, respectively. (Srinivas, T; Jain, K.C; Reddy, M.V and Reddy, M.S.S. 2000) ^[3] Table7.

100 Seed weight

Heterosis for 100 grain weight over better parent and mid parent along with their respective means and ranges are presented in Table 4.5.8. The extent of heterosis for 100 grain weight over mid parent ranged from -31.21(B3-13 X B1-169-1) to 17.35 (B1-51 X ICP7035). The extent of heterosis over better parent ranged from -17.38 (B1-51 X BRG-3) to 21.76 (B1-51 X ICP7035). (Wankhade, Rajesh. R; Wanjari, K.B; Kadam, G.M and Jadhav. B.P 2005) ^[2] Table 8.

Green pod yield per plant

Heterosis for green pod yield/plant over better parent and mid parent along with their respective means and ranges are maximum significant mid parent (873.17) and better parent (577.59) heterosis were recorded from the cross B1-141-1 X ICP7035. (Yadav, S.S. and Singh, D.P. 2004) ^[1] Table9.

Table 1: Heterosis (%) of plant height in the crosses

	Crosses	Better parent	Mid parent
1	B1-66-1X BRG-1	-15.63	-11.49
2	B1-66-1 X BRG-3	-23.93*	-21.92*
3	B1-66-1 X B1-169-1	-12.19	-10.75
4	B1-66-1 X 106-1	-17.35	-15.30
5	B1-66-1 X ICP-7035	-13.43	-2.31
6	B3-13 X BRG-1	-5.32	-4.60
7	B3-13 X BRG-3	-5.41	-2.55
8	B3-13 X B1-169-1	-9.72	-6.08
9	B3-13 X B2-106-1	-4.12	-1.06
10	B3-13 X ICP-7035	3.93	11.44
11	B2-5-2-1 X BRG-1	-5.59	-3.46
12	B2-5-2-1 X BRG-3	-3.53	-3.52
13	B2-5-2-1 X B1-169-1	0.69	1.70
14	B2-5-2-1 X B2-106-1	-0.65	-0.48
15	B2-5-2-1 X ICP-7035	-16.79	-8.28
16	B1-141-1 X BRG-1	-5.99	-2.65
17	B1-141-1 X BRG-3	-37.60**	-36.80**
18	B1-141-1 X B1-169-1	-10.17	-9.91
19	B1-141-1 X B2-106-1	-12.01	-11.03
20	B1-141-1 X ICP-7035	-0.19	11.30
21	B1-51 X BRG-1	-42.26**	-41.94**
22	B1-51 X BRG-3	-60.61**	-59.94**
23	B1-51 X B1-169-1	-18.17	-15.96
24	B1-51 X B2-106-1	-10.11	-8.42
25	B1-51 X ICP-7035	9.70	19.08
26	BRG-2 X BRG-1	-63.24**	-62.73**
27	BRG-2 X BRG-3	3.72	4.66
28	BRG-2 X B1-169-1	-42.08**	-40.98**
29	BRG-2 X B2-106-1	-63.69**	-63.30**
30	BRG-2 X ICP-7035	-58.56**	-54.68**
31	B2-10 X BRG-1	-14.99	-9.62

32	B2-10 X BRG-3	-11.97	-8.40
33	B2-10 X B1-169-1	4.64	7.84
34	B2-10 X B2-106-1		-5.46
35	B2-10 X ICP-7035	-9.85	2.98
SE		35.96	31.14
Range		-63.69-9.70	-63.30-19.08
Mean		-6.94	-3.05

Table 2: Heterosis (%) of Days to 50% flowering in the crosses

	Crosses	Better parent	Mid parent
1	B1-66-1X BRG-1	-0.60	-0.30
2	B1-66-1 X BRG-3	1.80	1.90
3	B1-66-1 X B1-169-1	1.00	1.61
4	B1-66-1 X 106-1	1.79	2.19
5	B1-66-1 X ICP-7035	-1.20	2.38
6	B3-13 X BRG-1	0.40	0.60
7	B3-13 X BRG-3	0.00	0.40
8	B3-13 X B1-169-1	0.61	0.71
9	B3-13 X B2-106-1	-0.20	0.70
10	B3-13 X ICP-7035	-0.61	2.50
11	B2-5-2-1 X BRG-1	-1.01	-0.91
12	B2-5-2-1 X BRG-3	0.00	0.30
13	B2-5-2-1 X B1-169-1	0.40	0.61
14	B2-5-2-1 X B2-106-1	-0.40	0.40
15	B2-5-2-1 X ICP-7035	0.00	3.23*
16	B1-141-1 X BRG-1	5.17**	5.80**
17	B1-141-1 X BRG-3	0.40	0.80
18	B1-141-1 X B1-169-1	0.20	1.10
19	B1-141-1 X B2-106-1	0.79	0.89
20	B1-141-1 X ICP-7035	-5.17**	-1.45
21	B1-51 X BRG-1	10.25**	12.43**
22	B1-51 X BRG-3	14.89**	16.93**
23	B1-51 X B1-169-1	-1.35	0.89
24	B1-51 X B2-106-1	-1.93	-0.69
25	B1-51 X ICP-7035	-2.51	2.65
26	BRG-2 X BRG-1	7.14**	7.89**
27	BRG-2 X BRG-3	-0.60	-0.10
28	BRG-2 X B1-169-1	10.12**	11.22**
29	BRG-2 X B2-106-1	9.52**	9.52**
30	BRG-2 X ICP-7035	6.55**	10.84**
31	B2-10 X BRG-1	1.00	1.40
32	B2-10 X BRG-3	0.40	0.60
33	B2-10 X B1-169-1	-1.40	-0.70
34	B2-10 X B2-106-1	-0.60	-0.30
35	B2-10 X ICP-7035	0.40	4.14**
SE		2.58	2.24
Range		-5.17-14.89	-1.45-16.93
mean		-0.12	0.70

Table 3: Heterosis (%) of primary branches in the crosses

	Crosses	Better parent	Mid parent
1	B1-66-1X BRG-1	-38.65	-35.30
2	B1-66-1 X BRG-3	-61.95	-59.40
3	B1-66-1 X B1-169-1	-36.45	-33.89
4	B1-66-1 X 106-1	-35.11	-31.60
5	B1-66-1 X ICP-7035	-47.23	-42.84
6	B3-13 X BRG-1	-26.37	-22.45
7	B3-13 X BRG-3	-10.58	-4.71
8	B3-13 X B1-169-1	-17.84	-14.64
9	B3-13 X B2-106-1	-21.69	-17.55
10	B3-13 X ICP-7035	-15.82	-8.70
11	B2-5-2-1 X BRG-1	-11.29	-10.07
12	B2-5-2-1 X BRG-3	-18.70	-16.58
13	B2-5-2-1 X B1-169-1	-17.95	-17.89
14	B2-5-2-1 X B2-106-1	-14.64	-13.51
15	B2-5-2-1 X ICP-7035	-41.24	-33.97
16	B1-141-1 X BRG-1	199.12**	225.09**
17	B1-141-1 X BRG-3	-31.41	-24.62
18	B1-141-1 X B1-169-1	-37.80	-33.29
19	B1-141-1 X B2-106-1	-29.22	-23.11
20	B1-141-1 X ICP-7035	-30.51	-26.96
21	B1-51 X BRG-1	-71.51*	-70.18*
22	B1-51 X BRG-3	-75.58*	-74.14*
23	B1-51 X B1-169-1	-36.91	-34.87
24	B1-51 X B2-106-1	-20.40	-16.73
25	B1-51 X ICP-7035	-6.78	1.73
26	BRG-2 X BRG-1	-81.78*	-80.88*
27	BRG-2 X BRG-3	17.41	24.64
28	BRG-2 X B1-169-1	-65.59	-64.39*
29	BRG-2 X B2-106-1	-77.73*	-76.65*
30	BRG-2 X ICP-7035	-72.88*	-70.48*
31	B2-10 X BRG-1	-35.85	-28.96
32	B2-10 X BRG-3	-25.57	-16.67
33	B2-10 X B1-169-1	-13.93	-5.91
34	B2-10 X B2-106-1	-15.73	-6.71
35	B2-10 X ICP-7035	-21.23	-18.84
SE		16.94	14.67
Range		-81.78-199.12	-80.88-225.09
mean		-26.52	-20.48

Table 4: Heterosis (%) of secondary branches in the crosses

	Crosses	Better parent	Mid parent
1	B1-66-1X BRG-1	40.77	94.67*
2	B1-66-1 X BRG-3	-71.40*	-69.57*
3	B1-66-1 X B1-169-1	-55.44	-48.91
4	B1-66-1 X 106-1	-55.16	-53.76
5	B1-66-1 X ICP-7035	-42.23	-35.33
6	B3-13 X BRG-1	2.28	45.52
7	B3-13 X BRG-3	-17.54	-8.37
8	B3-13 X B1-169-1	-19.60	-4.11
9	B3-13 X B2-106-1	-34.85	-29.73
10	B3-13 X ICP-7035	48.51	73.18*
11	B2-5-2-1 X BRG-1	20.63	58.33
12	B2-5-2-1 X BRG-3	-14.13	-12.75
13	B2-5-2-1 X B1-169-1	-11.71	-5.77
14	B2-5-2-1 X B2-106-1	-12.25	-7.97
15	B2-5-2-1 X ICP-7035	-40.81	-38.44
16	B1-141-1 X BRG-1	-32.36	-4.53

17	B1-141-1 X BRG-3	-12.88	-4.36
18	B1-141-1 X B1-169-1	-38.33	-27.26
19	B1-141-1 X B2-106-1	-24.83	-19.93
20	B1-141-1 X ICP-7035	14.01	31.44
21	B1-51 X BRG-1	-86.17	-83.21
22	B1-51 X BRG-3	-90.25*	89.06*
23	B1-51 X B1-169-1	-40.89	-38.62
24	B1-51 X B2-106-1	1.52	17.09
25	B1-51 X ICP-7035	126.06**	140.92**
26	BRG-2 X BRG-1	-92.17**	-89.48*
27	BRG-2 X BRG-3	121.45**	125.53**
28	BRG-2 X B1-169-1	-86.42*	-85.04*
29	BRG-2 X B2-106-1	-92.39**	-92.28**
30	BRG-2 X ICP-7035	-89.55**	-88.78**
31	B2-10 X BRG-1	-45.36*	-17.71
32	B2-10 X BRG-3	-44.30	-32.35
33	B2-10 X B1-169-1	-44.13	-27.78
34	B2-10 X B2-106-1	-47.91*	-38.37
35	B2-10 X ICP-7035	-29.63	-10.82
SE		64.59	55.93
Range		-92.39-126.06	-92.28-140.92
mean		-21.18	-15.91

Table 5: Heterosis (%) of pods per cluster in the crosses

	Crosses	Better parent	Mid parent
1	B1-66-1X BRG-1	-37.50*	-16.67
2	B1-66-1 X BRG-3	-57.14**	-45.45*
3	B1-66-1 X B1-169-1	-42.86*	-27.27
4	B1-66-1 X 106-1	-33.33	-20.00
5	B1-66-1 X ICP-7035	-10.00	28.57
6	B3-13 X BRG-1	-12.50	0.00
7	B3-13 X BRG-3	-14.29	-7.69
8	B3-13 X B1-169-1	28.57	38.46*
9	B3-13 X B2-106-1	16.67	16.67
10	B3-13 X ICP-7035	-10.00	12.50
11	B2-5-2-1 X BRG-1	-25.00	-7.69
12	B2-5-2-1 X BRG-3	14.29	33.33
13	B2-5-2-1 X B1-169-1	28.57	50.00**
14	B2-5-2-1 X B2-106-1	33.33	45.45*
15	B2-5-2-1 X ICP-7035	-40.00**	-20.00
16	B1-141-1 X BRG-1	-62.50**	-53.85**
17	B1-141-1 X BRG-3	-28.57	-16.67
18	B1-141-1 X B1-169-1	-42.86*	-33.33
19	B1-141-1 X B2-106-1	16.67	27.27
20	B1-141-1 X ICP-7035	-10.00	20.00
21	B1-51 X BRG-1	-62.50**	-53.85**
22	B1-51 X BRG-3	-57.14**	-50.00**
23	B1-51 X B1-169-1	-57.14**	-50.00**
24	B1-51 X B2-106-1	16.67	27.27
25	B1-51 X ICP-7035	-40.00**	-20.00
26	BRG-2 X BRG-1	-62.50**	-45.45*
27	BRG-2 X BRG-3	-14.29	20.00
28	BRG-2 X B1-169-1	-57.14**	-40.00
29	BRG-2 X B2-106-1	-50.00*	-33.33
30	BRG-2 X ICP-7035	-70.00**	-53.85**
31	B2-10 X BRG-1	-25.00	-20.00
32	B2-10 X BRG-3	14.29	14.29
33	B2-10 X B1-169-1	0.00	0.00
34	B2-10 X B2-106-1	0.00	7.69
35	B2-10 X ICP-7035	-50.00**	-41.18**
SE		0.42	0.36
Range		-70.00-33.33	-53.85-50.00
mean		-0.69	-2.29

Table 6: Heterosis (%) of pods per plant in the crosses

	Crosses	Better parent	Mid parent
1	B1-66-1X BRG-1	-59.78	-55.04
2	B1-66-1 X BRG-3	-91.68**	-90.48**
3	B1-66-1 X B1-169-1	-62.50	-54.28
4	B1-66-1 X 106-1	-78.61	-77.21
5	B1-66-1 X ICP-7035	32.56	37.66
6	B3-13 X BRG-1	75.36*	83.02*
7	B3-13 X BRG-3	-34.63	-30.08
8	B3-13 X B1-169-1	-11.89	13.58
9	B3-13 X B2-106-1	-38.06	-29.42
10	B3-13 X ICP-7035	28.23	32.87
11	B2-5-2-1 X BRG-1	-5.74	33.29
12	B2-5-2-1 X BRG-3	-40.81	-15.04
13	B2-5-2-1 X B1-169-1	94.58	113.85
14	B2-5-2-1 X B2-106-1	17.11	46.49
15	B2-5-2-1 X ICP-7035	-55.71	-40.39
16	B1-141-1 X BRG-1	-68.30	-63.89
17	B1-141-1 X BRG-3	-31.69	-20.43
18	B1-141-1 X B1-169-1	-22.52	-7.15
19	B1-141-1 X B2-106-1	-13.49	-9.69
20	B1-141-1 X ICP-7035	179.32**	196.15**
21	B1-51 X BRG-1	-92.11*	-88.69*
22	B1-51 X BRG-3	-90.64**	-86.38*
23	B1-51 X B1-169-1	-85.90	-84.18
24	B1-51 X B2-106-1	-16.99	5.65
25	B1-51 X ICP-7035	35.03	84.50
26	BRG-2 X BRG-1	-95.40**	-94.16*
27	BRG-2 X BRG-3	78.11*	130.23**
28	BRG-2 X B1-169-1	-79.47	-78.12
29	BRG-2 X B2-106-1	-93.66	-93.09
30	BRG-2 X ICP-7035	-92.54*	-91.10*
31	B2-10 X BRG-1	-53.65	-45.24
32	B2-10 X BRG-3	-13.83	3.95
33	B2-10 X B1-169-1	43.57	66.06
34	B2-10 X B2-106-1	-24.79	-24.72
35	B2-10 X ICP-7035	-12.94	-3.97
SE		53.91	46.69
Range		-95.40-179.32	-94.16-196.15
Mean		-24.22	-10.89

Table 7: Heterosis (%) of seeds per pod in the crosses

	Crosses	Better parent	Mid parent
1	B1-66-1X BRG-1	-6.67	-6.67
2	B1-66-1 X BRG-3	0.00	0.00
3	B1-66-1 X B1-169-1	-6.25	-3.23
4	B1-66-1 X 106-1	0.00	0.00
5	B1-66-1 X ICP-7035	13.33	13.33*
6	B3-13 X BRG-1	-13.33	-7.14
7	B3-13 X BRG-3	0.00	7.14
8	B3-13 X B1-169-1	0.00	10.34
9	B3-13 X B2-106-1	0.00	7.14
10	B3-13 X ICP-7035	0.00	7.14
11	B2-5-2-1 X BRG-1	-6.67	-6.67
12	B2-5-2-1 X BRG-3	-6.67	-6.67
13	B2-5-2-1 X B1-169-1	0.00	3.23
14	B2-5-2-1 X B2-106-1	0.00	0.00
15	B2-5-2-1 X ICP-7035	-6.67	-6.67
16	B1-141-1 X BRG-1	0.00	0.00
17	B1-141-1 X BRG-3	0.00	0.00
18	B1-141-1 X B1-169-1	-6.25	-3.23
19	B1-141-1 X B2-106-1	6.67	6.67
20	B1-141-1 X ICP-7035	20.00**	20.00**
21	B1-51 X BRG-1	-20.00**	-20.00**
22	B1-51 X BRG-3	-20.00**	-20.00**
23	B1-51 X B1-169-1	-12.50	-9.68
24	B1-51 X B2-106-1	0.00	0.00
25	B1-51 X ICP-7035	20.00**	20.00**
26	BRG-2 X BRG-1	-20.00**	-20.00**
27	BRG-2 X BRG-3	0.00	0.00
28	BRG-2 X B1-169-1	-25.00**	-22.58**
29	BRG-2 X B2-106-1	-20.00**	-20.00**
30	BRG-2 X ICP-7035	-20.00**	-20.00**
31	B2-10 X BRG-1	-6.67	-6.67
32	B2-10 X BRG-3	0.00	0.00
33	B2-10 X B1-169-1	6.25	9.68
34	B2-10 X B2-106-1	0.00	0.00
35	B2-10 X ICP-7035	6.67	6.67
SE		0.33	0.29
Range		-25.00-20.00	-22.58-20.00
Mean		-1.44	0.05

Table 8: Heterosis (%) of 100 seed (green) weight in the crosses

	Crosses	Better parent	Mid parent
1	B1-66-1X BRG-1	-5.92	-0.77
2	B1-66-1 X BRG-3	-5.12	0.68
3	B1-66-1 X B1-169-1	0.51	2.67
4	B1-66-1 X 106-1	-5.02	-0.35
5	B1-66-1 X ICP-7035	-8.63	-3.95
6	B3-13 X BRG-1	-5.31	-0.70
7	B3-13 X BRG-3	-7.73	-2.66
8	B3-13 X B1-169-1	-14.53**	-13.21**
9	B3-13 X B2-106-1	-2.14	2.07
10	B3-13 X ICP-7035	-7.35	-2.04
11	B2-5-2-1 X BRG-1	-8.90	-2.81
12	B2-5-2-1 X BRG-3	-16.07**	-9.92*
13	B2-5-2-1 X B1-169-1	-4.19	-0.96
14	B2-5-2-1 X B2-106-1	-4.41	1.44
15	B2-5-2-1 X ICP-7035	-3.65	0.11
16	B1-141-1 X BRG-1	-11.58*	-6.52
17	B1-141-1 X BRG-3	-5.56	0.44
18	B1-141-1 X B1-169-1	-8.72	-6.53
19	B1-141-1 X B2-106-1	-8.48	-3.76
20	B1-141-1 X ICP-7035	2.79	7.80
21	B1-51 X BRG-1	-8.52	-2.55
22	B1-51 X BRG-3	-17.38**	-11.47*
23	B1-51 X B1-169-1	-2.58	0.54
24	B1-51 X B2-106-1	-5.57	0.06
25	B1-51 X ICP-7035	12.76*	17.35**
26	BRG-2 X BRG-1	-10.83*	-3.43
27	BRG-2 X BRG-3	-9.94*	-1.90
28	BRG-2 X B1-169-1	-11.63*	-7.23
29	BRG-2 X B2-106-1	-12.24*	-5.45
30	BRG-2 X ICP-7035	-5.62	-3.46
31	B2-10 X BRG-1	-14.43*	-8.91
32	B2-10 X BRG-3	-14.73**	-8.69
33	B2-10 X B1-169-1	0.27	3.40
34	B2-10 X B2-106-1	-11.80	-6.61
35	B2-10 X ICP-7035	-4.50	-0.54
SE		1.30	1.13
Range		-17.38-12.76	-13.21-17.35
Mean		-5.26	-1.96

Table 9: Heterosis (%) of green pod yield per plant in the crosses

	Crosses	Better parent	Mid parent
1	B1-66-1X BRG-1	58.20	113.32
2	B1-66-1 X BRG-3	-63.78	-61.61
3	B1-66-1 X B1-169-1	5.53	10.01
4	B1-66-1 X 106-1	-65.54	-54.34
5	B1-66-1 X ICP-7035	327.76**	452.49**
6	B3-13 X BRG-1	367.53**	592.05**
7	B3-13 X BRG-3	105.64	150.08
8	B3-13 X B1-169-1	46.36	75.55
9	B3-13 X B2-106-1	-6.62	9.78
10	B3-13 X ICP-7035	151.85	260.15*
11	B2-5-2-1 X BRG-1	66.27	177.81*
12	B2-5-2-1 X BRG-3	15.67	69.89
13	B2-5-2-1 X B1-169-1	22.40	78.10
14	B2-5-2-1 X B2-106-1	41.09	56.76
15	B2-5-2-1 X ICP-7035	-35.62	5.23
16	B1-141-1 X BRG-1	-4.12	42.49
17	B1-141-1 X BRG-3	116.18	164.46
18	B1-141-1 X B1-169-1	30.32	57.26
19	B1-141-1 X B2-106-1	34.41	57.01
20	B1-141-1 X ICP-7035	577.59**	873.17**
21	B1-51 X BRG-1	-74.32	-64.10
22	B1-51 X BRG-3	-68.93	-65.29
23	B1-51 X B1-169-1	-78.39	-76.23
24	B1-51 X B2-106-1	12.96	43.71

25	B1-51 X ICP-7035	291.21**	425.59**
26	BRG-2 X BRG-1	88.97	-84.27
27	BRG-2 X BRG-3	534.53**	630.24**
28	BRG-2 X B1-169-1	-73.75	-70.24
29	BRG-2 X B2-106-1	-91.38	-89.30
30	BRG-2 X ICP-7035	-81.01	-73.92
31	B2-10 X BRG-1	130.08	185.85
32	B2-10 X BRG-3	308.53*	331.54**
33	B2-10 X B1-169-1	240.27	265.35*
34	B2-10 X B2-106-1	5.27	49.97
35	B2-10 X ICP-7035	257.30	322.29*
SE		118.29	102.44
Range		-91.38-577.59	-89.30—873.17
Mean		27.08	21.21

Conclusion

The estimates of significant heterosis over better parent indicated the true superiority of F₁s over better parent. Heterobeltiosis for green pod yield /plant of 577.59% and relative heterosis of 873.17% were recorded from the cross B1-141-1 x ICP7035 followed by 534.53 in the cross BRG2 x BRG3 for heterobeltiosis and 630.24 in BRG2 x BRG3 for relative heterosis suggesting the possibility of utilizing F₁ and further segregating generations in pigeonpea improvement programmes. Highly significant better parent heterosis as expressed by a number of crosses for various traits in the present study further suggested the possibilities of operating dominance mechanism of heterosis in these crosses of pigeonpea.

The author's input

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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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