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Prospects of hybrids in enhancing production and productivity of pigeonpea in Myanmar

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ABSTARCT

Fifteen pigeonpea hybrids developed by crossing four cytoplasmic-nuclear male-sterile (CMS) lines with nine fertility restorers were introduced from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India to Myanmar and evaluated at three locations. Hybrids 'ICPH 2671', 'ICPH 2673', 'ICPH 2740' and 'ICPH 3497' were found stable over the three environments and produced 1846 to 1967 kg/ha yield with 30.4 to 41.7% standard heterosis. 'ICPH 3461' (2217 kg/ha) was found suitable for Zaloke with 42.0% standard heterosis. In 36 on-farm trials, hybrid 'ICPH 2671' was 11.9 to 53.1% superior in yield over the control. The other promising hybrid 'ICPH 2740' (2247 kg/ha) also exhibited 70.0% standard heterosis in an on-farm trial conducted in Monwya township. Based on farmers' preference and yield, 'ICPH 2671' and 'ICPH 2740' were selected for further promotion. The large-scale hybrid seed production programme was also successful with 1596 to 2931 kg/ha hybrid seed yield. The results of present investigations showed that pigeonpea hybrids have potential for enhancing production and productivity of pigeonpea in Myanmar.

Key words: Heterosis, Hybrids, Pigeonpea, Productivity, Seed production, Stability

Myanmar is predominantly an agricultural country and pulses play an important role in its economy. Myanmar is the world's second largest exporter of pulses with the exports crossing 1.5 million tonne mark in 2009. Pigeonpea [*Cajanus cajan* (L.) Millsp.] is the third most important pulse crop of Myanmar and accounts for 14% of country's pulses production. It is predominantly cultivated as an intercrop with cotton (*Gossipium hirsutum*), groundnut (*Arachis hypogaea*), sesame (*Sesamum indicum*), greengram (*Vigna radiata*), and sunflower (*Helianthus annuus*) in Sagaing, Mandalay and Magway divisions of Central Dry Zone of Myanmar. According to Myanmar Agriculture Service (unpublished report), in the last 19 years pigeonpea has recorded significant increase in its area from 57,064 to 616,000 ha and production from 37,110 to 774,000 tonne. In spite of releasing six improved varieties in the last two decades in the country, the productivity (1111 kg/ha) of pigeonpea has not shown any sign of positive growth. To overcome this bottleneck, the researchers explored various options and recommended that adoption of high yielding hybrids can provide the derived answer. Therefore, 15 hybrid combinations were evaluated with the best local variety as control in multi-location and on-farm trials; and this paper summarizes their performance and discusses the prospects of hybrids in enhancing the productivity of pigeonpea in Myanmar.

MATERIALS AND METHODS

Fifteen medium duration pigeonpea hybrids, developed by crossing four CMS lines ('ICPA 2043', 'ICPA 2047', 'ICPA 2048' and 'ICPA 2092') containing A_4 cytoplasm (Saxena *et al.* 2005) and nine diverse fertility restorers ('ICPL 87119', 'ICPL 20205', 'ICPL 20107', 'ICPL 20128', 'ICPL 20096', 'ICPL 20108', 'ICPL 20111', 'ICPL 20098' and 'ICPL 20136') were introduced from ICRISAT, India. These hybrids were evaluated with the best available local check (cv. Monywashwedinga) at Myingyan, Sebin, and Zaloke research farms of Central Dry Zone during 2008-09 season. Each trial was conducted in a randomized complete block design with three replications. The experimental plots, measuring 5.4 m × 3.0 m, consisted of four rows that were sown 135 cm apart. The intra-row spacing was kept at 30 cm. According to the recommendations of Department of Agricultural Research (DAR), Myanmar, muriate of potash was applied as a basal dose @ 50 kg/ha of fertilizer. Three hand weedings were done at each location during the first two months of crop. Due to extended drought condition, two irrigations were provided to the crop at Zaloke, while at the other locations the experiments were grown under rainfed conditions. To control pod borers (*Maruca vitrata* Fab. and *Helicoverpa armigera* Hub.) two sprays of Dimethoate @ 750 ml/ha were done at flower initiation and early podding stages.

At each location data on days to maturity (no.), pods/plant (no.), seeds/pod (no.), 100-seed mass (g), and grain yield (kg/ha) were recorded on plot basis. The fertility restoration of each hybrid was estimated by visual examination of five fully grown floral buds collected randomly from each plant at Zaloke and Sebin. The standard heterosis (superiority of hybrid over control) for various traits was estimated using the method proposed by Meredith and Bridge (1972). To estimate the main and genotype x environment interaction effects for seed yield, the GGE biplot approach proposed by Yan *et al.* (2000) was used.

During 2009-10 season, hybrids 'ICPH 2671' and 'ICPH 2740' were evaluated in on-farm trials along with local control using farmers' cultural practices. The plot size for evaluating 'ICPH 2671' was 0.2 ha, while the performance of 'ICPH 2740' was assessed in 0.4 ha plot. Thirty-six on-farm trials of 'ICPH 2671' were sown in Sagaing and Mandalay divisions; while 'ICPH 2740' was evaluated in a solitary trial conducted in Monywa township of Sagaing division.

The hybrid seed production programme was undertaken in an isolated plot measuring 0.8 ha during 2009-10 cropping season at Tatkone research farm, using natural out-crossing of male-sterile line with its male counterpart (R-line) that was mediated by honey bees (*Apis mellifera*). Both the male and female parents were sown at the same time using a row ratio of 3 female: 1 male. The spacing between and within the rows was kept at 180 cm and 30 cm, respectively. Two additional rows of the pollinator were also grown on each side of the plot to enhance the pollen availability. The off-type plants observed during vegetative and early flowering stages were rogued. Two irrigations were given during the reproductive stage. To control pod borers one spray each of Dimethoate @ 750 ml/ha and Cypermethrin @ 750 ml/ha was applied at flower initiation and early podding stages, respectively. The seed multiplication of parents (A-/B- and R-lines) was also done at Tatkone research farm. The A-lines ('ICPA 2047' and 'ICPA 2092') and their maintainers ('ICPB 2047' and 'ICPB 2092') were sown in a row ratio of 4 female: 1 male in separate isolations. The plot size for multiplying each A-/B-line was 0.1 ha. The seed of R-lines was multiplied under controlled pollination using nylon nets.

RESULTS AND DISCUSSION

Fertility restoration of hybrids: ICRISAT developed a hybrid pigeonpea technology that is based on cytoplasmic-nuclear male-sterility and insect-aided natural out-crossing system (Saxena *et al.* 2006). The first ever testing of pigeonpea hybrids in Myanmar was undertaken in 2009 in three major pigeonpea growing divisions in collaboration with ICRISAT.

In any hybrid breeding programme, the pollen fertility of F_1 plants plays a major role in realizing high yields in the hybrids. The high quality of fertility restoration will assist in high number of pods on the F_1 hybrid plants. The fertility restoration of each hybrid was recorded in Sebin (20º N) and Zaloke (22° N). On average, the hybrids exhibited low level fertility restoration in Zaloke as compare to that of Sebin. Seven hybrids ('ICPH 2671', 'ICPH 2740', 'ICPH 2751', 'ICPH 3341', 'ICPH 3497', 'ICPH 3461' and 'ICPH 3491') exhibited high (> 90%) male-fertility at both the locations. In rest of the hybrids the pollen fertility ranged between 35 to 90%. Hybrid 'ICPH 3489' recorded 35% fertility restoration at Zaloke and 90% in Sebin. Similarly, hybrids 'ICPH 3337', 'ICPH 3462', 'ICPH 3467', 'ICPH 3759', 'ICPH 3477' and 'ICPH 3761' also showed a large variation for fertility restoration between the two environments (Fig. 1).

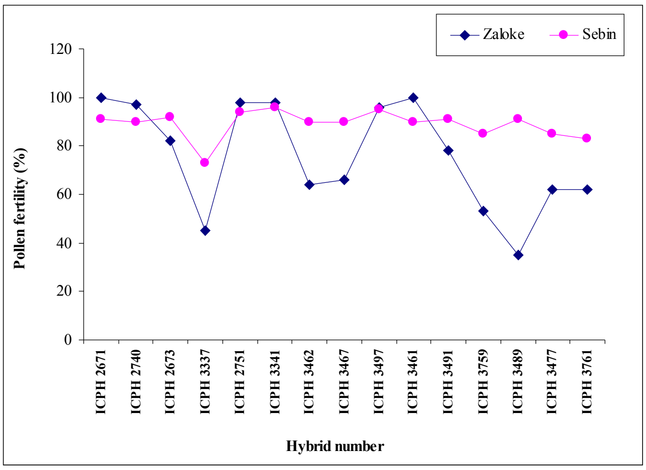

Fig 1. Variation for fertility restoration observed in pigeonpea hybrids in Zaloke and Sebin during 2008-09

According to Abdalla and Hermsen (1972), the variation in fertility restoration may be due to the presence of diverse fertility restoring genes. Kaul (1988) reported that hybrids may show significant variation in their pollen fertility due to differential inter-genomic or cytoplasmic-genomic interactions. In addition, the local environment also plays an important role in the expression of male-sterility (or) fertility. Saxena (2008) showed significant effects of sowing dates on the expression of pollen fertility in A_2 based pigeonpea hybrids. In another study, they also postulated that the hybrids carrying two dominant fertility restoring genes recorded higher male-fertility across the environments than those with a single dominant gene (Saxena *et al.* 2011). In the present study, among the 15 pigeonpea hybrids tested, seven were found to have high fertility restoration in different locations, while the others showed a considerable variation.

Standard heterosis for yield and related traits: In Myingyan, hybrids 'ICPH 3497' and 'ICPH 2740' expressed negative heterosis (early maturity) for maturity. In Sebin, all the hybrids matured earlier than the control and the standard heterosis ranged from -3.3 to -18.4%. In Zaloke, hybrids 'ICPH 3759' and 'ICPH 2673' took significantly more time to mature, while the remaining hybrids exhibited positive heterosis (1.0 to 6.6%) for maturity. Based on mean of the three locations, 'ICPH 3462' and local check (Monywashwedinga) matured at the same time, while 'ICPH 2673' matured later than the control. At Myingyan and Zaloke, all the hybrids were similar in maturity (Table 1).

In comparison to other locations, plant growth in Myingyan was poor due to extended drought experienced during the crop season. Hybrids 'ICPH 3341', '3761', '3467' and '3497' were significantly taller than the control with 4.1 to 8.8% standard heterosis. In Sebin, 'ICPH 3462' was the tallest followed by 'ICPH 3341', 'ICPH 3477' and 'ICPH 2673'. In Zaloke, 'ICPH 2740' recorded maximum height with 5.9% standard heterosis. Over all the environments, hybrids 'ICPH

Table 1. Performance of pigeonpea hybrids with respect to yield and related characters across three environments in Myanmar during 2008-09

Hybrid	Days to maturity				Plant height (cm)				100-seed mass (g)			
	Myingyan	Sebin	Zaloke	Mean	Myingyan	Sebin	Zaloke	Mean	Myingyan	Sebin	Zaloke	Mean
ICPH 3497	207	186	216	203	177	252	256	228	11.2	12.3	10.5	11.3
ICPH 2740	211	185	216	204	165	246	269	227	13.5	13.0	11.7	12.7
ICPH 2671	220	181	213	205	157	246	225	209	12.3	12.5	11.5	12.1
ICPH 2673	222	205	220	216	165	254	259	226	11.3	10.3	10.3	10.6
ICPH 3462	224	196	216	212	165	272	244	227	12.7	12.5	12.2	12.5
ICPH 3341	221	173	216	203	185	260	257	234	11.6	11.8	11.0	11.5
ICPH 3337	215	183	216	205	163	253	234	217	12.6	11.7	11.2	11.8
ICPH 2751	222	184	214	207	163	233	236	211	12.1	13.5	11.6	12.4
ICPH 3461	217	173	213	201	145	229	217	197	12.0	12.7	11.5	12.1
ICPH 3489	219	205	215	213	169	218	240	209	13.1	11.2	12.3	12.2
ICPH 3467	213	183	213	203	177	251	247	225	13.0	12.5	11.8	12.4
ICPH 3477	220	184	216	207	174	254	260	229	14.1	12.2	13.8	13.4
ICPH 3759	218	185	225	209	162	246	240	216	13.0	12.5	11.5	12.3
ICPH 3761	219	193	215	209	182	243	232	219	11.2	14.2	10.7	12.0
ICPH 3491	221	184	215	207	166	199	238	201	13.2	12.3	12.3	12.6
Local check	212	212	211	212	170	224	254	216	9.6	10.2	9.3	9.7
Mean	218	188	216	207	168	243	244	218	12.3	12.2	11.5	12.0
CV %	1.74	0.64	0.41	0.66	7.19	12.6	8.07	8.77	5.27	6.77	4.65	5.67
SEm	± 0.68	± 1.6	± 0.46	± 0.62	± 1.42	± 2.6	± 2.04	± 1.54	± 0.16	± 0.15	± 0.15	± 0.13

Table 1. contd….

Hybrid	Seeds/pod				Pods/plant				Yield kg/ha			
	Myingyan	Sebin	Zaloke	Mean	Myingyan	Sebin	Zaloke	Mean	Myingyan	Sebin	Zaloke	Mean
ICPH 3497	3.3	3.3	3.1	3.2	239	293	374	302	1685	1906	2309	1967
ICPH 2740	3.0	3.7	3.4	3.4	288	220	328	279	1665	1920	2302	1962
ICPH 2671	3.0	3.3	3.4	3.2	257	282	388	309	1890	1976	1917	1928
ICPH 2673	3.3	3.4	3.5	3.4	204	265	359	276	1255	2374	1908	1846
ICPH 3462	3.7	3.7	3.5	3.6	225	306	329	287	1634	2395	1325	1785
ICPH 3341	4.0	3.3	3.6	3.6	234	222	363	273	1575	1657	1987	1740
ICPH 3337	3.3	3.3	3.4	3.3	255	258	231	248	1696	1872	1504	1691
ICPH 2751	3.3	3.4	3.3	3.3	188	278	313	260	975	2041	2003	1673
ICPH 3461	3.0	3.6	3.0	3.2	177	208	404	263	1218	1435	2217	1623
ICPH 3489	3.3	3.6	3.3	3.4	102	247	275	208	1125	1817	1847	1596
ICPH 3467	3.3	3.3	3.5	3.4	215	301	302	273	1512	2142	1106	1587
ICPH 3477	3.7	3.7	3.4	3.6	114	229	337	227	921	1231	2259	1470
ICPH 3759	3.0	3.4	3.2	3.2	166	295	276	246	1070	1508	1642	1407
ICPH 3761	3.3	3.4	3.2	3.3	191	262	294	249	1151	1616	1298	1355
ICPH 3491	3.0	3.5	3.5	3.3	191	197	278	222	1138	877	1464	1160
Local check	3.7	3.4	3.4	3.5	210	244	295	250	1106	1526	1561	1398
Mean	3.3	3.5	3.4	3.4	204	257	322	261	1351	1768	1791	1637
CV %	13.3	6.0	6.1	7.41	25.7	11.1	26.4	18.0	21.2	14.6	14.4	16.4
SEm	± 0.04	± 0.02	± 0.02	± 0.2	± 7.11	± 5.55	± 6.84	± 3.63	± 44.16	± 58.06	± 55.76	± 33.92

3341' and 'ICPH 3477' were found stable for plant height. The seeds of hybrids 'ICPH 3477', 'ICPH 2740', 'ICPH 2751', 'ICPH 3467', 'ICPH 3759', 'ICPH 3491' and 'ICPH 3761' were bold; only two hybrids 'ICPH 3477' and 'ICPH 2740' were stable for seed size. The local check had the smallest seeds (Table 1).

In Myingyan, 'ICPH 3341' had significantly more number of seeds/pod as compared to the control and other hybrids. In Sebin, the hybrids 'ICPH 2740', 'ICPH 3462', 'ICPH 3461', 'ICPH 3489', 'ICPH 3491' and 'ICPH 3477' had more number of seeds/pod than the control (Table 1). In Zaloke, 'ICPH 3341' exhibited the highest number of seeds/pod with 5.9% positive heterosis.

In Myingyan, 'ICPH 2740' produced the highest number of pods/plant with 37.1% heterosis over the control. It was followed by 'ICPH 2671', 'ICPH 3337' and 'ICPH 3497' with 13.8 to 22.4% standard heterosis. Hybrids 'ICPH 3489' and

'ICPH 3477' showed significant negative (- 45.7 to - 51.4%) heterosis for pods/plant (Table 2). In Sebin, hybrid 'ICPH 3462' produced the highest number of pods/plant with 25.4% standard heterosis. In Zaloke, 'ICPH 3461' had the highest number of pods/plant, followed by 'ICPH 2671', 'ICPH 3497', 'ICPH 3341' and 'ICPH 2673' with 21.7 to 37.0% standard heterosis. Over all the locations, hybrids 'ICPH 3497' and 'ICPH 2671' produced greater number of pods/plant (Table 1).

In Myingyan, seven hybrids ('ICPH 3497', 'ICPH 2740', 'ICPH 2671', 'ICPH 3462', 'ICPH 3341', 'ICPH 3337' and 'ICPH 3467') produced significantly greater seed yield over the local check with 36.7 to 70.9% standard heterosis. On the contrary, hybrids 'ICPH 2751', 'ICPH 3477' and 'ICPH 3759' exhibited negative heterosis for seed yield. In Sebin, hybrids 'ICPH 3462', 'ICPH 2673', 'ICPH 3467', 'ICPH 2751' and 'ICPH 2671' demonstrated high yield (1976 to 2396 kg/ha) with 29.5 to 57.0% standard heterosis. In aloke, eight hybrids ('ICPH 3497', 'ICPH 2740', 'ICPH 2751', 'ICPH 3461', 'ICPH 3477', 'ICPH 2671', 'ICPH 2673' and 'ICPH 3341') produced high yields with 22.2 to 47.9% superiority over the local check (Table 2).

Historically, hybrid vigour has been exploited commercially in a number of cereals, vegetables, sunflower and cotton. In pigeonpea also, the CMS-based hybrid technology has provided optimism for its yield enhancement. So far, over 1500 experimental hybrids have been tested and promising hybrids with yield advantages of 25 to 156% over the best inbred variety (Kandalkar 2007, Saxena and Nadarajan 2010). Chauhan *et al*. (2008) reported 19.9 to 26.1% heterosis for yield in pigeonpea, and it was related to increased number of pods/plant, pod length, and seed size. In the present study,

Table 2. Standard heterosis (%) recorded in pigeonpea hybrids for different characters in three environments in Myanmar, 2008-09

Hybrid	Days to maturity				Plant height (cm)				100-seed mass (g)			
	Myingyan	Sebin	Zaloke	Mean	Myingyan	Sebin	Zaloke	Mean	Myingyan	Sebin	Zaloke	Mean
ICPH 3497	-2.4	-12.3	2.4	-4.1	4.1	12.5	0.8	5.8	16.7	20.6	12.9	16.7
ICPH 2740	-0.5	-12.7	2.4	-3.6	-2.9	9.8	5.9	4.3	40.6	27.5	25.8	31.3
ICPH 2671	3.8	-14.6	0.9	-3.3	-7.6	9.8	-11.4	-3.1	28.1	22.5	23.7	24.8
ICPH 2673	4.7	-3.3	4.3	1.9	-2.9	13.4	2.0	4.1	17.7	1.0	10.8	9.8
ICPH 3462	5.7	-7.5	2.4	0.2	-2.9	21.4	-3.9	4.9	32.3	22.5	31.2	28.7
ICPH 3341	4.2	-18.4	2.4	-3.9	8.8	16.1	1.2	8.7	20.8	15.7	18.3	18.3
ICPH 3337	1.4	-13.7	2.4	-3.3	-4.1	12.9	-7.9	0.3	31.3	14.7	20.4	22.1
ICPH 2751	4.7	-13.2	1.4	-2.4	-4.1	4.0	-7.1	-2.4	26.0	32.4	24.7	27.7
ICPH 3461	2.4	-18.4	0.9	-5.0	-14.7	2.2	-14.6	-9.0	25.0	24.5	23.7	24.4
ICPH 3489	3.3	-3.3	1.9	0.6	-0.6	-2.7	-5.5	-2.9	36.5	9.8	32.3	26.2
ICPH 3467	0.5	-13.7	0.9	-4.1	4.1	12.1	-2.8	4.5	35.4	22.5	26.9	28.3
ICPH 3477	3.8	-13.2	2.4	-2.4	2.4	13.4	2.4	6.0	46.9	19.6	48.4	38.3
ICPH 3759	2.8	-12.7	6.6	-1.1	-4.7	9.8	-5.5	-0.1	35.4	22.5	23.7	27.2
ICPH 3761	3.3	-9.0	1.9	-1.3	7.1	8.5	-8.7	2.3	16.7	39.2	15.1	23.6
ICPH 3491	4.2	-13.2	1.9	-2.4	-2.4	-11.2	-6.3	-6.6	37.5	20.6	32.3	30.1
Minimum	-2.4	-18.4	0.9	-5.2	-14.7	-11.2	-14.6	-9.0	16.7	1.0	10.8	9.8
Maximum	5.7	-3.3	6.6	1.9	8.8	21.4	5.9	8.7	46.9	39.2	48.4	38.3

Table 2. Contd….

ICPH No.	Seeds/pod				Pods/plant				Yield (kg/ha)			
	Myingyan	Sebin	Zaloke	Mean	Myingyan	Sebin	Zaloke	Mean	Myingyan	Sebin	Zaloke	Mean
ICPH 3497	-10.8	-2.9	-8.8	-7.5	13.8	20.1	26.8	20.2	52.4	24.9	47.9	41.7
ICPH 2740	-18.9	8.8	0.0	-3.4	37.1	-9.8	11.2	12.8	50.5	25.8	47.5	41.3
ICPH 2671	-18.9	-2.9	0.0	-7.3	22.4	15.6	31.5	23.2	70.9	29.5	22.8	41.1
ICPH 2673	-10.8	0.0	2.9	-2.6	-2.9	8.6	21.7	9.1	13.5	55.6	22.2	30.4
ICPH 3462	0.0	8.8	2.9	3.9	7.1	25.4	11.5	14.7	47.7	56.9	-15.1	29.9
ICPH 3341	8.1	-2.9	5.9	3.7	11.4	-9.0	23.1	8.5	42.4	8.6	27.3	26.1
ICPH 3337	-10.8	-2.9	0.0	-4.6	21.4	5.7	-21.7	1.8	53.3	22.7	-3.7	24.1
ICPH 2751	-10.8	0.0	-2.9	-4.6	-10.5	13.9	6.1	3.2	-11.8	33.7	28.3	16.7
ICPH 3461	-18.9	5.9	-11.8	-8.3	-15.7	-14.8	36.9	2.2	10.1	-6.0	42.0	15.4
ICPH 3489	-10.8	5.9	-2.9	-2.6	-51.4	1.2	-6.8	-19.0	1.7	19.1	18.3	13.0
ICPH 3467	-10.8	-2.9	2.9	-3.6	2.4	23.4	2.4	9.4	36.7	40.4	-29.1	16.0
ICPH 3477	0.0	8.8	0.0	2.9	-45.7	-6.1	14.2	-12.5	-16.7	-19.3	44.7	2.9
ICPH 3759	-18.9	0.0	-5.9	-8.3	-21.0	20.9	-6.4	-2.2	-3.3	-1.2	5.2	0.3
ICPH 3761	-10.8	0.0	-5.9	-5.6	-9.0	7.4	-0.3	-0.7	4.1	5.9	-16.8	-2.3
ICPH 3491	-18.9	2.9	2.9	-4.3	-9.0	-19.3	-5.8	-11.4	2.9	-42.5	-6.2	-15.3
Minimum	-18.9	-2.9	-11.8	-8.3	-51.4	-19.3	-21.7	-19.0	-16.7	-42.5	-29.1	-15.3
Maximum	8.1	8.8	5.9	3.9	37.1	25.4	37.0	23.2	70.9	56.9	47.9	41.7

significant standard heterosis was observed in multi-location trials and four hybrids ('ICPH 3497', 'ICPH 2740', 'ICPH 2671' and 'ICPH 2673') were found outstanding. It was also observed that yield of hybrids was positively related to number of pods/plant (r = 0.67**) and plant height (r = 0.57**).

In the multi-locational on-farm trials of hybrids 'ICPH 2671' and 'ICPH 2740', conducted over four years at 1281 locations in India, recorded 28.4 to 35.8% yield advantage over the local control (Saxena and Nadarajan 2010). Similarly in Myanmar also, the results of on-farm trials showed 11.9 to 53.1% standard heterosis for seed yield in hybrid 'ICPH 2671' and 70.0% in 'ICPH 2740'. These research findings showed that hybrid vigor can also be exploited for enhancing pigeonpea yields.

Stability analysis: The pooled analysis of data showed highly significant differences among genotypes (G) and environment (E) for yield and other traits (Table 3). The genotype x environment (G x E) interactions were also significant for all the characters except for plant height. The GGE biplot using Genotype plus Genotype × Environment (G + GE) interactions were studied. To achieve this, the total G+GE effect was separated from the observed mean and partitioned into multiplicative terms by using singular values decomposition (SVD) for the first (PC1) and second principal component (PC2). The PC1 and PC2 were eigenvectors for both the genotypes and environments that explained 49.55% variation by PC1 and 36.62% for PC2 with a total of 85.77%. The residual effect was not explained by the principal components for genotypes in a given environment. To construct a meaningful biplot, PC1 and PC2 eigenvectors were plotted after partitioning of singular values into the genotype and environment eigenvectors. Theoretically, the partitioning factors can take any value between 0 and 1. However, for this analysis a value of 0.5 was used to give equal importance to both the genotypes as well as environments.

Evaluation of environments: GGE biplot for yield showed that Myingyan and Sebin locations together may form a mega environment due to their closeness. On the contrary, Zaloke was distinct when compared with Myingyan and Sebin due to its obtuse angle observed between the environment vectors (Figure 2). The extended environment vector for Sebin suggested that this location should be considered for genotypic evaluation because of its greater ability to discriminate among the test materials.

Evaluation of genotypes: Hybrids 'ICPH 2671', 'ICPH 3497', 'ICPH 2740' and 'ICPH 2673' were considered stable for seed yield (Figure 2) due to their acute angle with Average Environment Axis (AEA). These hybrids also exhibited high mean yield (1746 to 1967 kg/ha) over the environments. Hybrid 'ICPH 3461' was found unstable due to its wide angle with AEA. However, it was better adapted to Zaloke where it produced 2259 kg/ha yield.

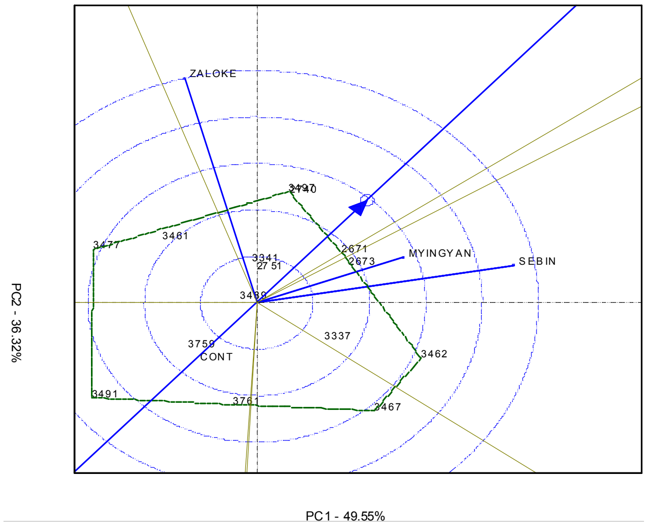

Fig 2. GGE biplot of PC1 against PC2 based on genotype and environment for seed yield

Performance of hybrids in farmers' fields: Eighteen on-farm trials involving hybrid 'ICPH 2671' and popular variety 'Monywashwedinga' were conducted in three townships of Sagaing division (Table 4). Over all the locations, 'ICPH 2671' produced average yield of 1166 kg/ha with 16.5% superiority over the local variety. In Sagaing division, this hybrid exhibited 29.4% standard heterosis in Monywa township; while in Depeyin its yield was similar to that of the local control. Due to late sowing and drought conditions in Myinmu, the yield levels of both the hybrid and control were low. In addition, 18 on-farms trials of 'ICPH 2671' were also conduced in Myingyan, Nhahtoegyi, and Taungtha townships in Mandalay division. In comparison to Sagaing the rainfall in Mandalay division was relatively less that resulted in low productivity. On average, 'ICPH 2671' produced 947 kg/ha yield with 12 to 53% standard heterosis. Hybrid 'ICPH 2740' was evaluated only in Monywa township where it produced 2247 kg/ha yield with 70.0% superiority over the local control.

Seed production of hybrids and their parents: For large-scale seed production, two promising hybrids 'ICPH 3461' and 'ICPH 2740' were identified. The seed production (A x R) of these hybrids was undertaken using a row ratio of 3 female: 1 male in 2009 rainy season. Since the success of hybrid seed production is determined by the extent of natural out-crossing that is primarily mediated by insects (Saxena *et al*. 1990), the seeds of sunflower were sown near the hybrid pigeonpea seed production plot to attract pollinators. At maturity, the restorer plants were harvested first and later the pods set due to out-crossing on the male-sterile plants were harvested. The pod setting on the male-sterile plants was good (1596 kg/ha) indicating abundance of pollinating insects. Similarly, hybrid 'ICPH 3461' produced 2931 kg/ha crossed seed.

The seed multiplication of the parental lines ('ICPA 2047' and 'ICPA 2092') was carried out in different isolations. The

Table 3. Pooled analysis of variance for yield and related traits

Source	d. f.	Mean sum of square					
		Days to maturity (no.)	Plant height (cm)	100-seed weight (g)	Pods/plant (no.)	Seeds/ pod (no.)	Seed yield (g)
Replications	6	1.54	2.05	0.26	2.43*	1.59	270998*
Genotypes (G)	15	100**	2.65*	6.81**	2.68*	1.80*	498126**
Environments (E)	2	394884**	466**	9.95**	424**	1274**	2950806**
G × E	30	99**	0.95	1.60**	3.29**	1.65*	357841**
Error	90	1.00	1.00	0.46	1.00	1.00	72422

Table 4. Performance of pigeonpea hybrids in farmers' fields in Myanmar (2009-10)

Division	Township	Hybrid name	Number of trials	Yield (kg/ha)		Standard heterosis (%)
				hybrid	check	
Sagaing	Monywa	ICPH 2671	6	1830	1414	29.4
Sagaing	Depeyin	ICPH 2671	6	1051	1051	0.0
Sagaing	Myinmu	ICPH 2671	6	619	542	14.2
Sagaing	Monywa	ICPH 2740	1	2247	1322	70.0
Mean				1167	1002	16.5
Mandalay	Myingyan	ICPH 2671	6	1300	1162	11.9
Mandalay	Nhahtoegyi	ICPH 2671	6	842	550	53.1
Mandalay	Taungtha	ICPH 2671	6	700	56 7	23.5
Mean				947	760	24.6
Mean/Total			36	1057	881	20.0

sets of male and female parents were sown using a row ratio of 4 A-line: 1 B-line. At maturity, the B-lines were harvested first and it was followed by harvesting the plants of A-lines. In these plots, 'ICPA 2092' yielded 1279 kg/ha of male-sterile seeds and 870 kg/ha of its maintainer; while 1010 kg/ha seed of 'ICPA 2047' and 600 kg/ha of 'ICPB 2047' were produced in another isolation. A total of six kilogram self-seed of R-line was harvested from 240 sq. ft area sown under nylon net.

The commercial hybrid seed production programme is known to play an important role in the adoption of hybrid technology; and its success was also ably demonstrated at Tatkone research station. The recorded hybrid yields were large enough to encourage seed producers to adopt this technology. Mula *et al*. (2010) reported that the estimated cost of hybrid pigeonpea seed in India was US $ 0.5/kg, while the selling retail price of the hybrid seed was around US $ 3-4/kg. They also showed that the cost-benefit ratio of hybrid seed production ranged between 1.85 and 6.32.

Based on the present findings, it was observed that among the pigeonpea hybrids evaluated in Myanmar, 'ICPH 2671' and 'ICPH 2740' were found the most promising; but the hybrid 'ICPH 2740' was more preferred due to its brown seed coat and uniform seed size. In the on-station trials, 'ICPH 2740' produced 1665 to 2302 kg/ha grain with 41.3% superiority over the control while 70.0% superiority in seed yield in an on-farm trial. 'ICPH 3461' with preferred seed colour was found suitable for Zaloke with high (2200 kg/ha) yield. Although in farmers' fields 'ICPH 2671' performed well in Sagaing and Mandalay divisions, it was relatively less preferred due to its dark purple seed colour. The success of hybrid seed production programme suggested its feasibility at commercial level and we would like to conclude that pigeonpea hybrids have potential to replace the existing local varieties in Myanmar. However, more research and development work is needed to enhance production and productivity of pigeonpea in Myanmar.

Prospects of hybrid pigeonpea: The overall performance of pigeonpea hybrids in different locations in the Central Dry Zone of Myanmar showed that the hybrids in general out-yielded the local variety by significant margins. The hybrid pigeonpea breeding programme at DAR is now focusing on the development of commercial hybrids using locally adapted germplasm. Under this initiative, a total of 61 hybrid combinations were made and among these, 13 exhibited 90 to 100% fertility restoration. These hybrids will be evaluated in multi-locational trials within the country. At the same time, seed multiplication of the female and male parents will be carried out to produce quality hybrid parent seeds. The adoption of pigeonpea hybrids in the near future is expected to give greater profits to the farmers of Myanmar through increasing the production and productivity of the crop.

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