Rapid generation advancement in chickpea

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Development of homozygous lines from segregating populations following hybridization takes several years if one generation is taken every year. Plant breeders have used various methods to accelerate generation turnover. In chickpea (*Cicer arietinum*), many breeding programs successfully take two generations per year – one in the field during the crop season and the other in off-season either in greenhouse or in an off-season nursery. In India, chickpea is grown in winter season and sowing generally starts in October. The length of crop season varies from 90 to 160 days depending on latitude, altitudes and growing conditions (soil type, irrigation, etc). The off-season crop is taken during summer in the high latitude areas, eg, Lahaul and Spiti in Himalayas (latitude 31°44’ to 32°59’ N, longitude 76°46’ to 78°41’ E, altitude 5,480 to 6,400 m). Similar off-season nurseries are available in many other countries, eg, Terbol in the Beqaa valley in Lebanon (latitude 33°47’ N, longitude 35°59’ E, altitude 1220 m).

It is possible to accelerate generation turnover further by taking three generations per year in short-season environments. At the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India, we have been successfully doing this for short- and medium-duration crosses. As Patancheru (near Hyderabad in Andhra Pradesh) is located at 17°53’ N latitude, 78°27’ E longitude and 545 m altitude, the chickpea crop season is very short (90 to 120 days). One generation is taken in field during the crop season (October to January) and two in greenhouse during the off-season (February to September). Early flowering in greenhouse is induced by providing 24-h day length by using incandescent lights, as described by Sethi et al. (1981). Most genotypes flower in 25 to 35 days after sowing and later the light treatment is discontinued. The crop is harvested in about three months making it possible to take two generations in off-season. However, there are some limitations of off-season generation advancement in greenhouse. It is expensive and number of crosses and population size are restricted to the space available in greenhouse. Thus, this method can be used only for few crosses. Generations in greenhouse are usually advanced using single-seed-descent (SSD) method and start from F_2 onwards. The F_1s are invariably grown in field during the main crop season

Table 1. Weather data for Patancheru, India during the experimental period.

Month	Rainfall (mm)	Evaporation (mm)	Max temp (°C)	Min temp (°C)	Relative humidity (%) Morning (07:17 h)	Relative humidity (%) Afternoon (14:17 h)	Solar radiation (mj m^{-2})	Bright sunshine (h)
Jan 06	0	134	29.1	11.5	89.8	31.4	17.5	9.8
Feb 06	0	179	32.5	13.8	80.4	22.6	19.9	10.4
Mar 06	45	217	33.5	19.2	85.2	35.6	20.7	9.3
Apr 06	128	225	36.5	21.8	76.2	30.5	22.1	9.3
May 06	30	281	37.4	23.6	71.0	32.2	22.1	9.1
Jun 06	59	196	33.3	23.4	83.5	50.7	17.0	5.6
Jul 06	154	218	31.8	22.9	88.3	65.3	14.8	4.1
Aug 06	198	140	29.6	22.1	89.2	68.5	14.5	4.4
Sep 06	203	120	30.5	21.8	92.9	66.7	16.2	5.2
Oct 06	43	126	30.3	19.4	93.7	54.2	15.8	7.0
Nov 06	17	108	28.7	17.4	93.8	52.5	14.7	6.5
Dec 06	0	115	28.5	12.7	95.5	40.9	16.2	8.8
Jan 07	0	136	29.4	13.0	96.0	45.0	16.3	9.0

Table 2. Comparative performance of chickpea genotypes in winter and spring seasons at ICRISAT, Patancheru, India.

Genotype	Season	Time to flower (days)	Time to maturity (days)	Plant height (cm)	No. of pods $plant^{-1}$	Filled pods (%)	No. of seeds $plant^{-1}$	100-seed weight (g)	Yield $plant^{-1}$ (g)
Desi lines									
ICCV 98920	Winter	38	104	35.1	84	97	89	18.1	16.5
	Spring	45	84	35.3	44	96	54	14.9	7.7
ICCV 94924-3	Winter	34	100	38.5	104	97	124	16.0	19.5
	Spring	35	83	34.8	46	95	49	15.2	7.4
ICCV 98905	Winter	41	106	34.4	72	94	69	21.6	15.1
	Spring	37	80	31.1	54	88	57	15.5	8.9
ICCV 94920-3	Winter	38	110	34.7	82	96	95	18.3	17.3
	Spring	37	85	30.7	53	90	59	16.3	9.5
JG 130	Winter	50	110	42.4	78	97	93	22.7	21.2
	Spring	46	85	37.3	30	91	31	20.5	6.4
ICCV 98902	Winter	39	104	36.0	54	93	50	28.5	14.5
	Spring	38	81	35.8	44	89	46	21.5	10.4
ICCV 92944	Winter	38	102	36.7	53	93	52	23.4	12.3
	Spring	34	78	33.3	35	94	34	21.6	7.2
ICCV 98907	Winter	42	104	37.0	47	84	41	27.6	11.7
	Spring	36	82	36.2	25	86	25	24.1	6.0
ICC 4958	Winter	41	102	41.4	62	93	61	31.8	19.1
	Spring	35	83	45.9	31	85	27	31.0	8.4
Kabuli lines									
ICC 11299	Winter	67	138	50.5	13	96	13	50.2	6.1
	Spring	58	110	49.7	19	95	19	34.8	6.7
ICC 13820	Winter	58	128	55.4	39	89	36	42.1	14.6
	Spring	59	120	45.4	24	88	23	35.4	8.1
ICCV 95334	Winter	50	112	46.0	40	93	38	46.2	17.7
	Spring	35	83	43.0	27	88	26	38.7	10.4
ICCV 96329	Winter	37	102	40.6	48	90	53	35.0	16.0
	Spring	32	84	42.1	29	88	25	41.4	9.9
ICC 14220	Winter	52	112	47.8	31	93	30	46.3	13.6
	Spring	34	95	42.2	20	94	21	41.6	8.5
ICC 14200	Winter	51	114	44.7	27	92	28	43.1	12.2
	Spring	33	86	40.3	28	90	26	43.1	11.3
ICC 17109	Winter	47	116	46.0	34	84	29	62.7	18.5
	Spring	33	100	51.9	20	92	20	47.8	9.5
ICC 14195	Winter	49	110	53.0	19	89	18	58.9	10.5
	Spring	37	87	41.6	15	95	15	48.4	7.0
ICC 14206	Winter	47	114	47.6	21	90	20	56.6	11.3
	Spring	33	90	38.9	27	90	25	49.8	12.3
Average of desi lines	Winter	40.2	104.7	37.4	70.7	93.8	74.9	23.1	16.3
	Spring	38.1	82.3	35.6	40.2	90.5	42.4	20.1	8.0
	Change (%)	–5.2	–21.3	–4.7	–43.1	–3.5	–43.4	–13.2	–51.1
Average of kabuli lines	Winter	50.9	116.2	48.0	30.2	90.5	29.3	49.0	13.4
	Spring	39.3	95.0	43.9	23.2	91.2	22.2	42.3	9.3
	Change (%)	–22.7	–18.3	–8.5	–23.0	0.7	–24.4	–13.6	–30.6

to maximize the number of F_2 seeds. As SSD is generally used for advancing generations in greenhouse, it is particularly useful for development of recombinant inbred lines (RILs). We are routinely developing RILs by taking three generations per year.

We have recently revisited and refined an alternative cost-effective procedure of rapid generation advancement where two generations are taken in field during winter and spring seasons and one in pots during the rainy season using low-cost rainout shelters to prevent the crop from excess rain. This makes possible to fast track large number of crosses. The first crop is sown during end of September to first week of October and harvested by mid or end of January. This cycle, called winter crop or main season crop, is the one preferred for generating F_2 seeds. The second crop is sown during mid-January to first week of February, immediately after the harvest of the first crop and harvested by the end of April. This second cycle is called spring crop. The winter crop can be harvested at physiological maturity (yellowing of pods and foliage) and the plants sun-dried for few days before threshing. The seed can be sown immediately after threshing. The winter crop can be grown rainfed but the spring crop requires irrigation almost every fortnight.

The spring crop faces relatively high temperatures, low relative humidity, high evaporation and high solar radiation, particularly at the reproductive stage, compared to the winter crop (Table 1). For comparing the performance of the winter and the spring crop, we grew 18 fixed lines (germplasm/cultivars/advanced breeding lines) along with segregating populations. These included nine desi lines and nine kabuli lines (Table 2). As expected, the spring crop flowered early and took 18 to 21% less time to mature. It is generally believed that kabuli types are more adapted to cooler long-season environments. Thus, we expected that desi types would perform better in spring season as the temperatures were high during reproductive stage. It was interesting to see that seed yield reduction in spring crop as compared to the winter crop was less in kabuli type (30.6%) than in desi type (51.4%). On average desi type gave 21.6% higher seed yield than the kabuli type in winter season, whereas kabuli type gave 16.2% higher seed yield than the desi type in spring season. This was mainly due to less reduction in number of pods per plant in kabuli type (23%) than the desi type (43.4%). The reduction in seed size was almost similar (13.2 to 13.6%) in both types. The results give an indication that the kabuli types are more tolerant to high temperature than the desi types. There are genotypic variations for relative performance in winter and spring seasons, giving opportunity for selecting high temperature tolerant genotypes. Thus, the second crop is not only useful for generation advancement, but can also be used for screening of genotypes for high temperature tolerance.

The spring crop produced reasonable seed yield and can even be used for seed multiplication of breeding lines. We are now able to advance large number of crosses using this method. After taking two generations in the field, the third crop is taken during the rainy season (June to September) under low-cost movable rainout shelters. The plants are grown in pots and are covered with rainout shelters all the time during night and when raining during day. As bright sunshine hours are less during rainy season (Table 1), additional light is provided to extend photoperiod and induce early flowering. Initially 24-h photoperiod is provided to initiate early flowering (as described earlier for greenhouse) and later reduced to 12 h.

Rapid generation advancement by taking 2–3 generations per year is important in chickpea for accelerating process of varietal development particularly when the double haploid technology is yet to be standardized for this crop. The countries with environmental conditions similar to southern India, having short chickpea season (eg, Myanmar), can try to take three generations per year, as described in this article, to accelerate generation turnover.

Reference

Sethi SC, Byth DE, Gowda CLL and **Green JM.** 1981. Photoperiodic response and accelerated generation turnover in chickpea. Field Crops Research 4:215–225.