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Soybean MAGIC population: a novel resource for genetics and plant breeding

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The acronym MAGIC that stands for 'multiparent advanced generation intercross' is a powerful next generation mapping population to precisely map the agronomically important quantitative trait loci. An eight parent based soybean MAGIC population was developed by employing 2-way, 4-way and 8-way intercross hybridization. The aim was to obtain MAGIC-derived breeding lines with higher yield, broader genetic base, increased diversity and variability. The 8-way and 4-way intercross hybrids so developed in the present study will be evaluated for their yield potential in the subsequent generation under changing climatic conditions (F_2–F_8 generation).

Keywords: High-throughput genotyping, quantitative trait, multiparent, 8-way hybrids.

THE demand placed currently on food production globally requires greater advances in genetic improvement in cereals and pulse crops. A crucial step towards enhancing the productivity of food crops entails rapid identification of gene(s) and their utilization in plant breeding to provide better control and delivery of agronomic traits. Traditional approach for identification of such genetic elements based on biparental mapping populations is found to have some drawbacks[1–3]. The major problems associated with biparental mapping populations are lower allelic diversity; inappropriate for fine mapping (of quantitative trait loci (QTLs)) due to low level recombination events; creation of narrow genetic base in the derived breeding lines which leads to susceptibility to biotic and abiotic stresses. Further, identifying genes that have smaller effects on quantitative traits is more difficult. Many QTL mapping studies have been conducted in different crops but few have pinpointed causal genes[3]. In order to address these problems, multiparent-based mapping populations have been created and extensively studied for various quantitative traits in *Arabidopsis thaliana*[4], wheat[5,6], rice[7] and are underway in a variety of other crops[8].

Worldwide, a number of studies are presently in progress to exploit the multiparent advanced generation intercross (MAGIC)-derived breeding lines. The evaluation of multi-genotype based varieties for yield and associated traits under multi-location test indicated superior performance of MAGIC-derived lines over biparental derived lines in rice[1]. In wheat, eight parent MAGIC

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Table 1. Details of the parents used in development of MAGIC population

Name of parent	Characteristic feature
JS 335	Wider adaptable variety with resistance to bacterial pustule[14].
JS 95-60	A popular variety of central India resistance to girdle and blue beetle, root rot, bacterial pustule[14].
NRC 37	A popular variety of central India having moderately resistance to collar rot, bacterial pustule, pod and bud blight[14].
NRC 86	A new variety of central India with high degree of resistance to bacterial pustule and pod blight[14].
EC333901	A promising line collected from USA for higher yield and its attributing traits[15].
EC546882	A promising line collected from Brazil for higher yield and its attributing traits[15].
EC572136	A diverse and high yielding line collected from China[15].
EC572109	Promising line collected from China for higher yield and its attributing traits[16].

Figure 1. Soybean MAGIC population developed at ICAR-Indian Institute of Soybean Research Indore. The plants derived from 8-way F_1 were grown under net house condition during *kharif* 2016.

population was found superior to biparental population in capturing maximum genetic diversity as well as maximum SNP marker segregation[9]. High definition QTL mapping of quantitative traits like rhizospere size[10], heading date and plant height[11] were successfully accomplished using MAGIC populations in different crops. Selection for earliness in wheat using MAGIC population is also well established by fine mapping QTL responsible for heading time[12]. Study on genetic basis of natural variation of seed size and number using a set of *Arabidopsis thaliana* MAGIC lines indicated both seed size and seed number are governed by non overlapping QTL, suggesting that seed size and seed number can evolve independently[13].

The MAGIC-derived lines are a new panel of genetically diverse and highly recombinant inbred lines (RILs) and represent a significant improvement over standard RILs that descend from just two parents. The higher density of recombinants helps in improving mapping resolution[7]. Therefore, the mapping accuracy and detection are much improved in multiparent based RILs when compared to traditional two-parent F_2 and RIL mapping populations[4]. The derived lines also have broader genetic base which is largely contributed by eight genotypes and three rounds of hybridization events involved in generating segregating populations. Consequently, MAGIC-RILs are an important, new, plant genetic resource for better understanding of genetic basis of plant growth and yield under multiple environments, for example, they are used to study the effect of climate change on soybean productivity. Modern agriculture, based on biparental crop varieties have contributed tremendously to the world's food supply. However, the strategy is also being challenged due to stagnation in yield growth, climate change, susceptibility to biotic and abiotic stresses, etc. Multi-parental breeding approach (MAGIC approach) is a promising strategy to understand more about important genomic regions to address these major challenges.

The present study reports potential utilities and creation of a MAGIC population by completing 2-way (four combinations), 4-way (six combinations) and 8-way hybridization in three combinations to represent all eight parents in single hybrids. Eight founder parents consisting of four popular soybean varieties, viz. JS 335, JS 95-60, NRC 37, NRC 86 and four promising exotic collections from three different countries, viz. EC546882 (Brazil), EC333901 (USA), EC572109 (China) and EC572136 (China) were employed in three rounds of intercrossing programme. The four cultivars were chosen based on their maximum (>85%) acreage under cultivation in India whereas, the other four exotic collections were chosen based on their high yield performance under multilocation evaluation. The relevant details of the parents used in the study are presented in Table 1. For developing the MAGIC population, traits targeted from the selected parents were higher yield and attributing traits, wider adaptability, resistance to bacterial pustule, pod blight, blue beetle, collar rot, etc. One more objective of the present study was to bring diversity from China, Brazil and USA in the genetic background of Indian soybean cultivars.

For the development of initial four combinations of 2-way crosses, viz. EC572109 × JS 95-60, EC572136 × JS 335, EC546882 × NRC 37 and EC333901 × NRC 86, seeds of eight founder parents were sown under polyhouse during *kharif* 2013 at different sowing dates to match the flowering time of the respective parental pairs.

Table 2. Details of the 2-way and 4-way intercrosses (DCHs) performed during the *kharif* 2013 and 2014 respectively.

Type of intercross	Genotypic combinations	No. of pods harvested	No. of seeds
2-way intercross	EC572109 × JS 95-60	71	102
	EC572136 × JS 335	64	75
	EC546882 × NRC 37	53	105
	EC333901 × NRC 86	66	115
	Total	254	417
4-way intercrosses	[EC546882 × NRC37] × [EC572136 × JS335]	39	58
	[EC546882 × NRC37] × [EC333901 × NRC86]	64	105
	[EC546882 × NRC37] × [EC572109 × JS9560]	49	76
	[EC333901 × NRC86] × [EC572136 × JS335]	75	135
	[EC572109 × JS9560] × [EC572136 × JS335]	31	52
	[EC572109 × JS9560] × [EC333901 × NRC86]	145	211
	Total	403	637

Hybridization was attempted pairwise among eight parents to produce a total 417 F_1 seeds. During *kharif* 2014, F_1 seeds from EC572109 × JS 95-60, EC572136 × JS 335, EC546882 × NRC 37 and EC333901 × NRC 86 were sown under polyhouse condition in different batches to ensure pollen and flower bud availability for longer period. Hybridity of these F_1s was confirmed through morphological markers, viz. stem pigmentation, flower colour and pubescence. After confirmation of hybridity, 4-way inter-crosses (double crosses) were attempted in six combinations and a total of 637, 4-way inter-cross hybrid seeds were harvested (Table 2) which were again sown during *kharif* 2015 and tested for their hybridity through morphological markers. Only true hybrid seeds were used again in three cross combinations to produce 8-way hybrids. A total of 764 eight-way hybrids (Figure 1) along with F_2 seeds from six combinations of 4-way hybrids were harvested and kept for evaluating their yield performance and other traits.

In brief, multi-parent breeding lines derived from four-parent and eight-parent based hybrids developed in the present study will be evaluated under multi location testing to exploit diversity, variability, broader genetic base and also to obtain better plant types that are suitable for changing environments.

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