

Cite this article: Singh KV, Jafarullakhan SS, Vanniarajan C, Kannan B, Jagadeeswaran R, Sivakumar R, Sudhagar R. Unravelling the trait genetics in cool season legumes using generation mean analysis. Plant Science Today. 2026; 13(sp2): 1-7. <https://doi.org/10.14719/pst.14058>

Supplementary tables

Supplementary Table 1. Chickpea generation mean analysis (GMA) studies

Sl. No.	Year	Traits	GMA model	Scaling test	Genetic parameter	Reference
1.	2012	PS, PBrC/P, SBrC/P, PoC/P, NS/Po, HSW, and SY/P	Three and six parameters	Joint	χ^2 significant for all traits	(10)
					3 parameter model M effects: For all traits	
					6 parameter model M + I effects: PS, HSW, and SY/P M + [i] effects: SBrC/P, PoC/P and NS/Po M + [i], [l] effects: PBrC/P	
2.	2013	FiFD, MD, PS, FB/P, PoC/P, NS/Po, BY/P, SY/P, H.I, HSW, and PC	Five parameters	Combined	Duplicate epistasis: PS, PBrC/P, HSW, and SY/P, while epistasis was absent for other traits	(11)
					C&D scales: all traits	
					χ^2 significant for all traits	
3.	2013	HSW	Six parameters	Combined	[d], [h], [i], and [l]: Most of the traits (except HSW where [h], and [l] components are absent)	(12)
					Duplicate epistasis: most of the traits (except HSW)	
					ABCD scales: all traits	
					χ^2 non-significant	(12)
					M + I effect	

					Duplicate epistasis ABCD scales: all traits (except D scale)	
4.	2015	PS, MD, NB/P, PoC/P, H.I, and SY/P	Six parameters	Combined	M + I effects: all traits	(13)
					Duplicate epistasis: all traits χ^2 significant for all traits	
5.	2015	FiFD, MD, PBrC/P, PoC/P, HSW, and SY/P	Three and six parameters	Joint	M + I effect: PoC/P; M + [i], [l] effects: MD; [d], [h] + I effect: FiFD; [h], [i], [l]: SY/P; [h] and [l]: PBrC/P, and HSW	(14)
					Duplicate epistasis: most of the traits (except FiFD) C&D scales: Most of the traits (except PFWD where the C scale was non-significant; NS/P- both scales were absent)	
					χ^2 non-significant for all traits	
6.	2016	DMF, PBrCMF, SBrCMF, PSMF, PoC/P, WPoPP, NS/P, WS/P, and TSW	Three and five parameters	Combined	3 parameters M effects: DMF, PSMF, PBrCMF, SBrCMF, WPoPP, and TSW; [m] and [d]: PoC/P, and WS/P & [m] and [h]: NS/P	(15)
					5 parameters M + [i], [l] effects: DMF, PBrCMF, PSMF, and TSW [m], [d], and [l]: SBrCMF, WS/P; [m], [h], [i] and [l]: PoC/P; [m], [d], [h], [i]: WPoPP & [m]: NS/P	
7.	2017	FiFD, DPI, MD, PS, PBrC/P, H.I, SBrC/P, PoC/P, and BY/P	Five parameters	Joint	Duplicate epistasis: most of the traits (except NS/P) M + [i], [l] effects: all traits	(16)
					C&D scales: all traits	
8.	2018	DF(1 st), PS, MD, PoC/P, NS/P, NS/Po, SY/P, BY/P, and HSW	Five parameters	Combined	M + [i], [l] effects: PS, MD, NS/P, NS/Po, SY/P, and HSW; M + [l] effects: BY/P & [m], [d], [i], and [l]: DF(1 st), and PoC/P	(17)

					Duplicate epistasis: DF(1 st), PS, MD, SY/P, BY/P, and HSW & Complimentary epistasis: PoC/P, NS/P, and NS/Po	
					χ^2 significant mostly (except PBrC/P, and NS/P)	
9.	2020	FiFD, MD, PBrC/P, PS, PoC/P, NS/Po, HSW, SY/P, BY/P, and H. I	Six parameter	Joint	[m]: PBrC/P, and NS/Po; [m] + I effects: H.I; [m], [d], and [j]: FiFD; [m], [j], and [l]: MD & M + I effect: PS, PoC/P, HSW, SY/P, and BY/P	(18)
					Duplicate epistasis: most of the traits (except PBrC/P, and NS/Po)	
10.	2022	NPo/P, BY/P, H.I, NS/P, HSW, SY/P, NHPo/P and LPoHG	Six parameter	Joint	χ^2 significant for all traits M + I effects: all traits	(19)
					Timely sown	
					ABCD scales: both traits	
					χ^2 Significant for both traits	
11.	2022	FiFD and MD	Six parameter	Combined	M + I effect: MD (both environment conditions <i>i.e.</i> , timely and late sown), and FiFD: late sown	
					Duplicate epistasis: MD	
					Late sown	
					ABCD scales: both traits	
					χ^2 Significant for both traits	(20)
					M + [i], [j] effects: FiFD: timely condition.	
					Duplicate epistasis: FiFD, and MD	

					Timely planting	Delayed planting	
					ABCD scales: most of the traits (except B scale in PrBr/P)	ABCD scales: most of the traits (except B scale in PrBr/P, and A scale in ScBr/P)	
12.	2024	PrBrC/P, SBrC/P, NPo/P, HSW, SY/P, and BY/P	Six parameter	Combined	No epistasis: PrBr/P, SY/P	No epistasis: PrBr/P, NPo/P	(21)
					Duplicate epistasis: ScBr/P, HSW, and BY/P	Duplicate epistasis: ScBr/P, HSW, SY/P, BY/P	
					[m], [i], [l]: PrBr/P M + [i], [l]: ScBr/P, Npo/P, M + [i], [j], [l]: HSW, and BY/P [m], [h] +I effects: SY/P	[m], [h] + I effects: PrBr/P M+ [i], [l]: ScBr/P, M+ [i],[j]: NPo/P M+I effects: HSW, SY/P, and BY/P	
13.	2024	DF(1 st), PS, PoC/P, NS/P, PrBrC/P, SBrC/P and PWH	5 parameter	Combined	C&D scales: all traits M+ [i] and [l] effects: all traits χ^2 significant for all traits Duplicate epistasis: all traits		(22)
					ABCD scales: most of all traits (except D in DF(1 st), PoC/P and HSW; A in MD, PS, PBrC/P, SBrC/P, PoC/P, number of Seeds per pod and SY/P; B in PS, PBrC/P, SN/Po, HSW and SY/P) χ^2 significant for all traits M+I effects: most of the traits Duplicate epistasis: only in MD, PS, PBrC/P, SN/Po, HSW, and RWC		
14.	2025	DF(1 st), MD, PS, PBrC/P, SBrC/P, PoC/P, SN/Po, HSW, SY/P, and RWC	6 parameter	Combined			(23)

PS: plant stature; PBrC/P: primary branches count per plant; SBrC/P: secondary branches count per plant; PoC/P: pods count per plant; WS/P: weight of seeds per plant; WPoPP: weight of pod per plant; PSMF: plant stature at maximum flower; PBrCMF: primary branches count at maximum flower; SBrCMF: secondary branches count at maximum flower; MD: maturity duration; HSW: 100-seed weight; FB/P: fruiting branches/plant; FiFD: fifty per cent flowering duration; SY/P: seed yield/plant; DMF: days to maximum flower; TSW: 1000-seed weight; DPl: days to pod initiation; HI: harvest index; NS/Po: number of seed per pod; BY/P: biological yield per plant; PC: protein content; NB/P: number of branches per plant; DF(1st): days to 1st flowering; NS/P: number of seeds per plant; PWH: plant weight at harvest; RWC: relative water content; SN/Po: seed number per pod; NS/P: number of seeds per plant; NHPo/P: number of hollow pods per plant; LPoHG: lowest pod height from the ground; M effect: [m], [d], and [h]; I effect: [i], [j] and [l]; combined: Individual scale + Joint scale; χ^2 – chi square.

Supplementary Table 2. Common bean generation mean analysis (GMA) studies

Sl. No.	Year	Traits	GMA model	Scaling test	Genetic parameter		Reference
1.	2013	PS, PL, StC, QtY, LA, NPo/P, NS/P, SY/P, AGB, and H.I	Six parameters	Combined	<u>Non-stress</u> ABCD scales: most of the traits (except PS, H.I in A; PL, SY/P, AGB in C; StC in B; CT, NPo/P in B&C; and QtY and LA in A&C scales; all traits D scale) M + [i], [l] effects: NPo/P [m], [h], [i], [l]: NS/P M + I effect: StC, CT, and SY/P; M + [i] effects: QtY, and LA; M + [i], [j] effects: AGB [m], [h], [i]: H.I, PL; [m], [j]: PS Duplicate epistasis: all traits	<u>Drought stress</u> ABCD scales: most of traits (except PH, NPo/P, NS/P, and H.I in A&B; AGB, and SY/P in B&C; PL and LA in AC; CT and QtY in B scale; all traits D scale) M + I effect: NPo/P, and CT M + [i], [j] effects: NS/P, StC M + [i] effects: SY/P, and LA M + [i], [l] effects: PS, and NPo/P; [m], [h], [i]: same as non-stress; [m], [h], [i], [j]: QtY Epistasis: same as the non-stress condition	(28)
2.	2014	PoC/P, PoW, SN/P, SN/Po, SY/P, and HSW	Three and Six parameters	Combined	ABCD scales: most of traits (except PNPP in A; SNPP in C; PoW in D) χ^2 significant for all traits 3 parameter M effects: most of all traits (except for PoC/P where only [m] present) 6 parameter [m], [h], + I effect: PoC/P; M + [j], [l] effects: PoW; M + I effect: SN/Po, SY/P, and HSW; [m], [j], [l]: SN/P Duplicate epistasis: all traits		(29)
3.	2015	PS, NB/P, NL/P, PL, PoW, PoC/P, GPoW, NS/Po, and SY/P	Five parameters	Combined	C&D scales: all traits χ^2 significant for all traits		(30)

					M + [i], [l] effects: PS, PL, and PoW; M effects: GPoW; [m], [h], [i], [l]: NB/P, PoC/P; [m], [h], [l]: NL/P; [m], [h]: SY/P; [m], [l]: NS/Po	
4.	2021	HRN, HRL, and BRWN	Three and Six parameters	Joint	Duplicate epistasis: all traits χ^2 significant for all traits	(31)
					3 parameters M effects: HRL; [m], [d]: HRN; [m], [h]: BRWN	
					6 parameters M + [i], [j] effects: HRL; [m], [d], [l]: HRN; [m], [i], [j]: BRWN	
5.	2023	Bacterial brown spot	Six parameters	Combined	ABCD scales: only A&C scale is significant	(32)
					M + [i] and [l] effects	
					Duplicate epistasis	
PoC/P: pods count per plant; NS/P: number of seeds per plant; SY/P: seed yield per plant; PS: plant stature; AGB: above-ground biomass; HI: harvest index; PoW: pod weight; SN/P: seed number per plant; SN/Po: seed number per pod; HSW: 100-seed weight; HRN: hypocotyl root number ; HRL: hypocotyl root length; BRWN: basal root whorl number; StC: stomatal conductance; CT: canopy temperature; QtY: quantum yield and LA: leaf area.						

Supplementary Table 3. Pea generation mean analysis (GMA) studies

Sl. No.	Year	Traits	GMA model	Scaling test	Genetic parameter	Reference
					ABCD scales: most the of traits (except FiFD in the A scale; DTP, and NS/Po in ABD scales; PL in all scales; PS in the B scale; TSS in the D scale)	
					χ^2 significant for PoC/P	
1.	2012	FiFD, DTP(1 st), NS/Po, PL, SH %, PS, PoC/P, PoY/P, PMI, T.S.S, and PC	Six parameters	Combined	[d], [h] + I effect: FiFD, PS, PoC/P, PoY/P, PMI, T.S.S., and PC; [d]: DTP(1 st), and PL; [d], [h], [i]: NS/Po; [d], [h], [i], [l]: SH %	(39)
					Duplicate epistasis: most of the traits & Epistasis absent: DTP(1 st), PL, and NS/Po	

2.	2012	NBP/LA, NNB/LA, PS, NAC/P, and AUDPC	Six parameters	Joint	M + [i], [l] effects: NBP/LA; M + l effect: NNB/LA, PS, and AUDPC; M + [i], [j] effects: NAC/P Duplicate epistasis: most of the traits & Epistasis absent: NAC/P ABCD scales: only significant in PL, and PS in A; PL, and DTP in B & D; DTP, and PS in C	(40)
3.	2013	FiFD, DTP(1 st), PS, PL, PoC/P, PoY/P, and PMI	Six parameters	Combined	χ^2 significant in PS, and PMI [d], [h], [j]: DTP(1st); [d], [h] [i], [j]: PL, PS, PoY/P Duplicate epistasis: PL, NS/Po, SH %, PoC/P, and PMI & In remaining traits, Epistasis type absent ABCD scales: most of the traits (except NBF(1st), FiFD, PL, and NS/Po in A; PL, and PoG in B; FiFD, PL, PoG, and NS/Po in C; PL in D).	(41)
4.	2015	PS, NBF(1 st), FiFD, PL, PoG, NS/Po, and TY/P	Six parameters	Combined	χ^2 significant for most of the traits (except PL) [m], [d], [l]: PS; [m], [h], [i], [l]: NBF(1st), and PL M + [l] effects: FiFD; M + [i], [l] effects: TY/P; M + [i] effects: PoG; [m], [l]: NS/Po Duplicate epistasis: most of the traits & Epistasis absent: NS/Po, and PS M + l effect: PS, CC/P, PL, SS %, PoC/P, HSW, and SY/P; M effects: PoC/C; [m], [h], [i], [l]: BrC/P; [m], [h], [j], [i]: MD; [m], [l]: DTF(1st)	(42)
5.	2017	DTF(1 st), BrC/P, MD, PS, CC/P, PL, SS %, PoC/C, PoC/P, HSW, and SY/P	Six parameters	Joint	Duplicate epistasis: DTF(1st), BrC/P, PS, SS %, PoC/C, PoC/P, and SY/P & Complimentary epistasis: remaining traits ABCD scales: most of the traits (except DTF in A; PL in D; NS/Po in AB&D; SH % in B)	(43)
6.	2021	DTF, DTP(1 st), PL, NS/Po, SH %, PS, PoC/P, and PoY/P	Six parameters	Combined	χ^2 significant for all traits [m], [d]: DTF; [m], [d], [j]: DTP(1st); [m], [d], [j], [l]: PL; M + [i], [j] effects: NS/Po; M + l effect: PS; M + [i] effects: PoC/P; M effects: PoY/P	(44)

					Duplicate epistasis: most of traits & Epistasis absent: DTF	
					ABCD scales: most of all traits (except A scale in NPBr)	
7.	2024	NBFiF, TNNNo, NPNNo, NPBr, NPo/P, PL, PoW, NS/Po WPo/P, HSWF, and HSWD	Six parameters	Combined	M + I: all traits	(45)
					χ^2 significant for all traits	

FiFD: fifty per cent flowering duration; DTP(1st): days to 1st picking; NS/Po: number of seeds per pod; PL: pod length; SH %: shelling percentage; PS: plant stature; PoC/P: pods count per plant; BrC/P: branches count per plant; CC/P: cluster count per plant; PoC/C: pod count per cluster; PoY/P: pod yield/plant; PMI: powdery mildew incidence; TSS: total soluble solids; PC: protein content; NBP/LA: number of bursting pustules per cm² of leaf area; NNBP/LA: number of non-bursting pustules per cm² of leaf area; PS: pustule size; NAC/P: number of aecial cups per pustule; and AUDPC: area under disease progress curve; NBF(1st): node bearing 1st flower; PoG: pod girth; TY/P: total yield per plant; DTF(1st): days to 1st flowering; MD: maturity duration; SS %: seed setting percentage; HSW: 100-seed weight; SY/P: seed yield per plant; DTF: days to 1st flowering; SH %: shelling percentage; NBFiF: node bearing first flower; TNNNo: total number of nodes; NPNNo: number of productive nodes; NPBr: no. of productive branches, PoW: pod width; NS/Po: number of seeds per pod; WPo/P: weight of pod per plant; HSWF: hundred seed weight fresh and HSWD: hundred seed weight dry.

Supplementary Table 4. Broad bean generation mean analysis (GMA) studies

Sl. No.	Year	Traits	GMA model	Scaling test	Genetic parameter	Reference
					ABCD scales: most of the traits (except PS, NB/P, PoC/P, HSW, SY/P in A; PS, and HSW in B; NB/P, and HSW in C; all traits in D)	
1.	2013	PS, NB/P, PoC/P, HSW, SY/P	Six parameters	Combined	M + [i] and [l] effects: PS, NB/P [m] and [d]: PoC/P, and HSW; [m], [h], + I effect: SY/P	(52)
					Duplicate epistasis: all traits	
					ABCD scales: most of the traits (except PS, and NB/P in C; HSW in D)	
2.	2013	PS, NB/P, PoC/P, NS/P, SY/P, and HSW	Six parameters	Combined	M + I effect: PS, NB/P, PoC/P, NS/P, and SY/P; M + [j] effects only: HSW	(53)
					Duplicate epistasis: all traits	
					ABCD scales: most of the traits (except NS/Po, CS, and RS in B)	
3.	2014	PS, NB/P, PoC/P, NS/Po, SY/P, HSW, CS, and RS	Six parameters	Combined	M + I effect: most of all traits (except in CS and RS); M + [i] effects: CS; M + [i], [j] effects: RS	(54)
					Duplicate epistasis: all traits	

					ABCD scales: most of the traits (except NS/Po in A; PS, and NB/P in B; PoC/P in C)	
4.	2015	DF, MD, PS, NB/P, PoC/P, NS/P, SY/P, NS/Po, HSW, CS, and rust	Six parameters	Combined	M + I effect: all traits	(55)
					Duplicate epistasis: all traits	
					M + [i], and [l] effects: all traits	
5.	2018	FiFD, MD, PS, NB/P, NC/P, PL, PoC/P, NS/Po, HSW, and SY/P	Five parameters	Joint	Duplicate epistasis: for majority of traits & Complimentary epistasis: PS, NB/P, and NS/Po	(56)
					ABCD scales: most of the traits (except HSW in A and D; DF, PS, NB/P, and PoC/P in D)	
6.	2018	DF, PS, NB/P, PoC/P, NS/P, SY/P, and HSW	Six parameters	Combined	M + I effect: all traits	(57)
					Duplicate epistasis: all traits	
7.	2019	NB/P, PoC/P, NS/P, SY/P, HSW, PS, CS, and rust	Six parameters	Joint	M + I effect: NB/P, and PoC/P; M effect: rust; M + [i], [l] effects: CS; M + [i], [j] effects: HSW; [m], [d]: PS; [m], [i], [l]: SY/P; [m], [h], + I effect: NS/P	(58)
					Duplicate epistasis: all traits	
					ABCD scales: most of the traits (except H.I in A; NB/P in ABCD)	
8.	2020	DF, PS, BY/P, SY/P, H.I, NB/P, PoC/P, NS/P, and HSW	Six parameters	Combined	χ^2 significant for most of the traits (except NB/P)	(59)
					M + I effects: PS, BY/P, and H.I; M + [i] effects: SY/P; M + [i], [l] effects: NS/P, and HSW; [m], [h] + I effect: PoC/P; [m], [d], [i], [l]: DF; [m], [h]: NB/P	
					Duplicate epistasis: BY/P, SY/P, H.I, PoC/P, and NS/P; Complimentary epistasis: DF, PS, and HSW & Epistasis absent: NB/P	
					C&D scales: all traits	
9.	2023	MD, PS, NB/P, PoC/P, NS/P, and SY/P	Five parameters	Combined	M + [i], and [l] effects: MD, PS, and PoC/P; [m], [d], [i], and [l]: NB/P, NS/P, and SY/P	(60)

					Duplicate epistasis: all traits	
10.	2023	PS, NB/P, PoC/P, NS/P, SY/P, CS, and rust	Six parameters	Joint	M + I effect: PS, and rust; M + [i], [j] effects: NB/P M + [i], [l] effects: PoC/P; [m], [h], + I effect: NS/P, SY/P, and CS	(61)
					Duplicate epistasis: all traits ABCD scales: most of the traits (except DF, and NB/P in A & B scales)	
11.	2023	FiFD, MD, PS, NB/P, PoC/P, NS/P, SY/P, NS/Po, HSW, CSDR, and RDR	Six parameters	Combined	M + I effect: most of all traits (except PS, and NB/P); M + [i], [j] effects: PS; M + [i] effects: NB/P	(62)
					Duplicate epistasis: all traits ABCD scales: all traits M + I effects: all traits	
12.	2024	FiFD, CS, RDR, PS, NB/P, PoC/P, NS/P, SY/P and HSW	Six parameters	Combined	Duplicate epistasis: all traits	(63)

PS: plant stature; MD: maturity duration; NB/P: number of branches per plant; PoC/P: pod count per plant; NS/P: number of seeds per plant; SY/P: seed yield per plant; CS: chocolate spot disease reaction; FiFD: fifty per cent flowering duration; NC/P: number of clusters per plant; PL: pod length; NS/Po: number of seeds per pod; HSW: 100-seed weight; CSDR: chocolate spot disease reaction and RDR: rust disease reaction.

Supplementary Table 5. Lentil generation mean analysis (GMA) studies

Sl. No.	Year	Traits	GMA model	Scaling test	Genetic parameter	Reference
1.	2012	SY/P, PH, NPo/P, NS/P, No. of PrBr, NScBr, NC/P, PL, NoS, NS/Po and HSW	Three and Six parameters	Combined	ABC scaling- most of all traits (except AC in NPrBr, NS/Po; ABC in PL) 3 parameter M effects: all traits (except d in HSW) χ^2 significant for all traits 6 parameter M effects: all traits [i]: except PH, NPo/P, NS/P, PL, NS/Po, HSW [j]: except SY/P, PH, NPo/P, NS/P, NC/P, PL, NoS, HSW [l]: except PL χ^2 non-significant all traits	(67)

					Duplicate epistasis: all traits (except PL)	
2.	2021	DF, PHFF, NPBFF, NSBFF, CAMF, NSBMF, NPdPP, PdWPP, NSPP, SWPP, IPIW, RW	Three parameters	-	[m]: NPBFF [m] and [d]: NSBFF, CAMF, NSBMF, SWPP and RW [m] and [h]: NPdPP and NSPP M effects: DF, PHFF, PdWPP and IPIW χ^2 significant for all traits	(68)

SY/P: seed yield per plant; PH- plant height; NPo/P: number of pods per plant; NS/P: number of seeds per plant; NPrBr: number of primary branches; NC/P: number of cluster per plant; PL: pod length; NoS- number of nodes per mainstem; NScBr: number of secondary branches; NS/Po: number of seeds per pod; HSW: hundred seed weight; DF: days to flower; PHFF: plant height at first flower; NPBFF: number of primary branch at first flower; CAMF: canopy area at first flower; NSBMF: number of secondary branch at maximum flower; NPdPP: number of pods per plant; PdWPP: pod weight per plant; NSPP: number of seeds per plant; SWPP: seed weight per plant; IPIW: individual plant weight and RW: root weight.