

Supplemental Information

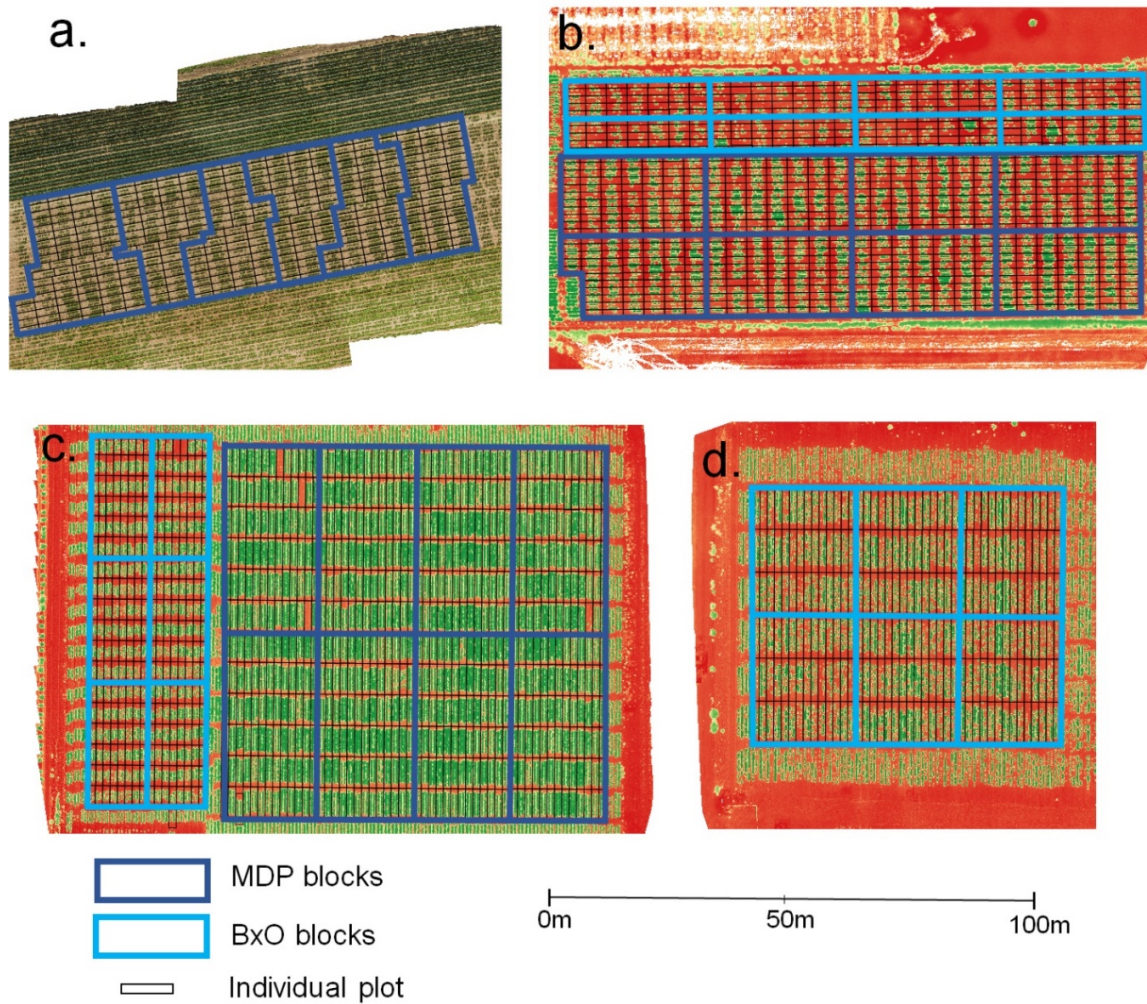


Figure S1. Layouts of evaluated fields in (a) 2016, (b) 2017, (c) 2018, and (d) 2019. The Middle American Diversity Panel (MDP) was grown 2016–2018, while the Black Nightfall x Orca (BxO) recombinant inbred population was grown 2017–2019. In each year, the field was separated into blocks with replicated controls in each block to account for spatial effects (augmented design, Federer and Raghavarao 1975). MDP blocks are indicated by dark blue boxes, BxO blocks are in light blue. Thin black lines represent plot shapefile boundaries for data extraction. All fields are represented to scale with one another.

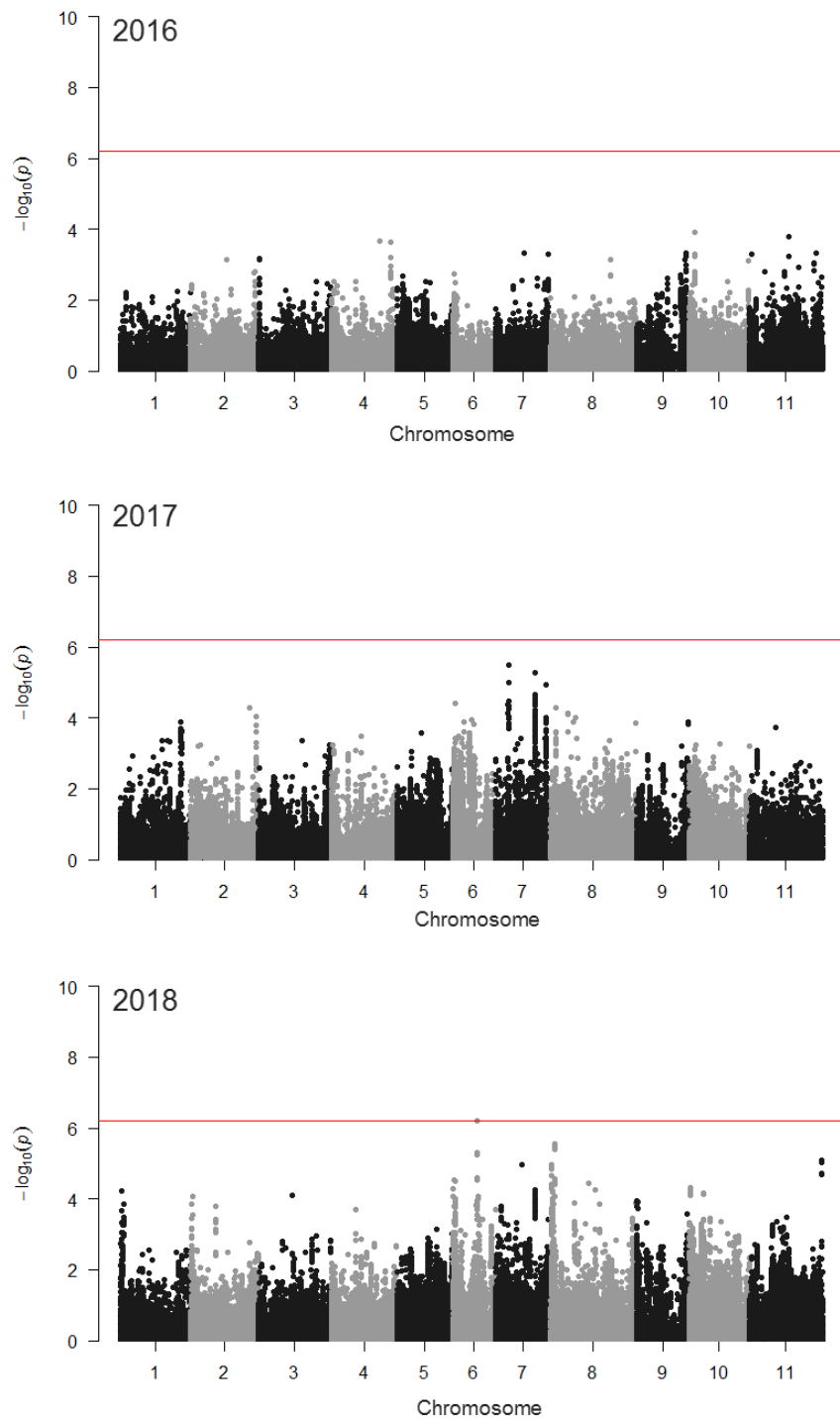


Figure S2. GWAS of seedling emergence rate in the Middle American Diversity panel. A SNP on Pv06 (LOD = 6.19) approached significance based on a conservative Bonferroni threshold (LOD = 6.21) of 2018 data. GWAS conducted in TASSEL based on a general linear model through the SNIPlay interface.

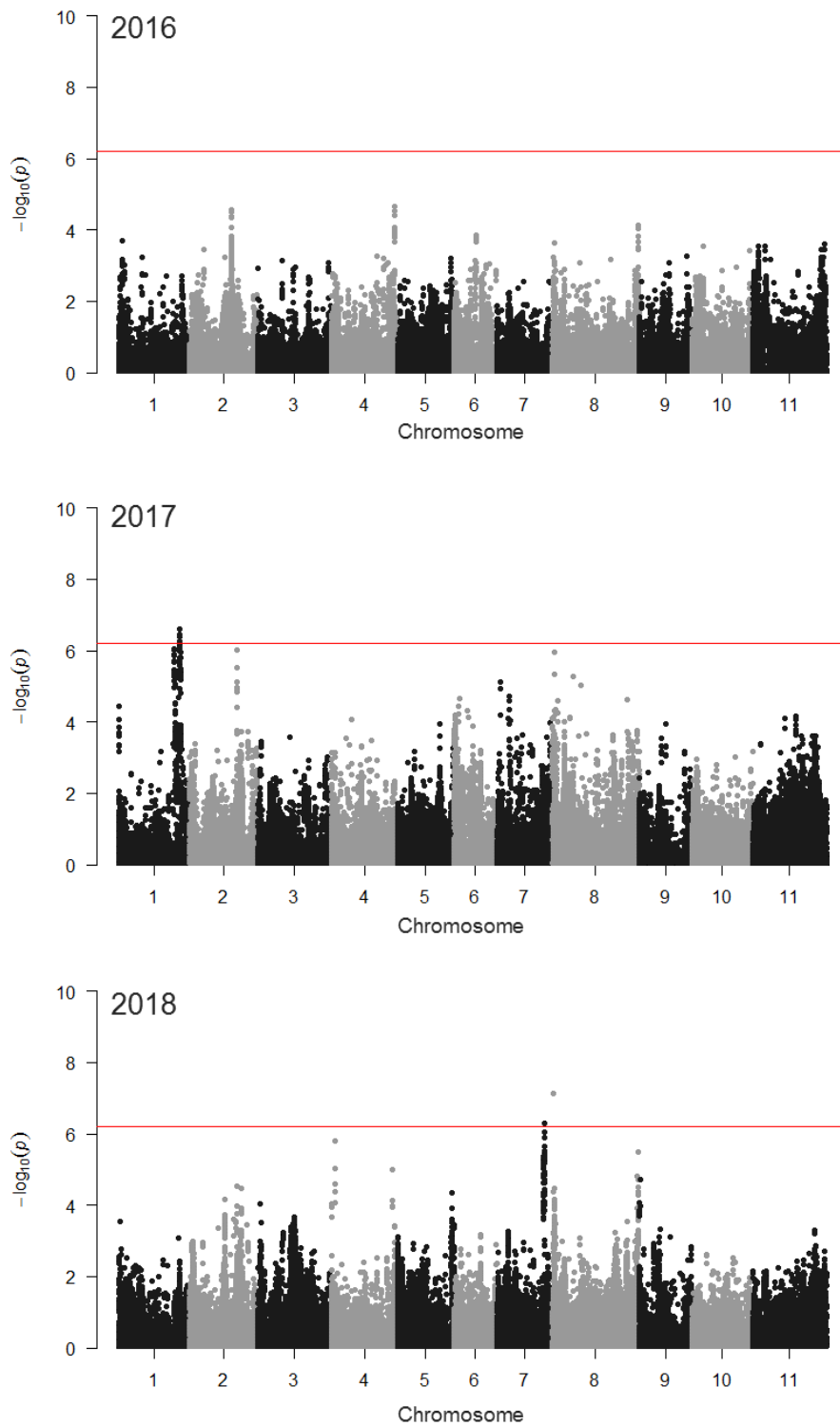


Figure S3. Hand-measured canopy height GWAS in the MDP. In 2017, a significant QTL was identified near PvTFL1y on chromosome Pv01. In 2018, the Pv07 locus associated with growth rate was also associated with hand-measured canopy height. GWAS conducted in TASSEL based on a general linear model through the SNIPlay interface. See Table S3 for more information on significant SNPs.

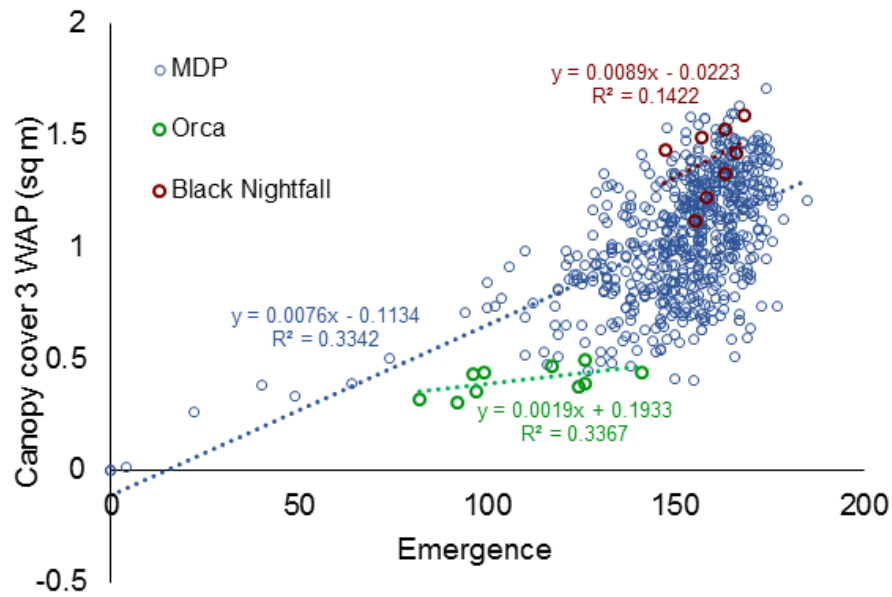


Figure S4. 2018 emergence and growth rate in the Middle American diversity panel, including Black Nightfall and Orca plots as controls. The x axis represents the number of seeds germinated out of 180 seeds planted. Black Nightfall has stronger seedling emergence, and above-average growth rates, even after emergence correction. Orca has lower emergence, and below-average growth rates relative to types with similar emergence rates.

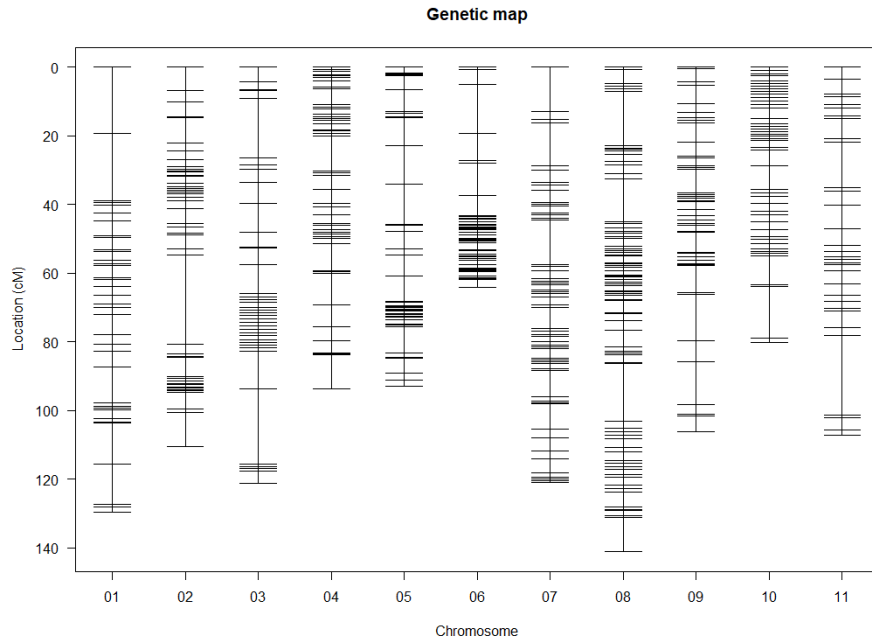


Figure S5. Black Nightfall \times Orca (B \times O) population linkage map: Linkage groups (vertical lines) were ordered and oriented to correspond with the 11 chromosomes of the common bean reference genome[46,47]. A total of 730 markers (horizontal bars) were distributed across 1138cM of recombination space.

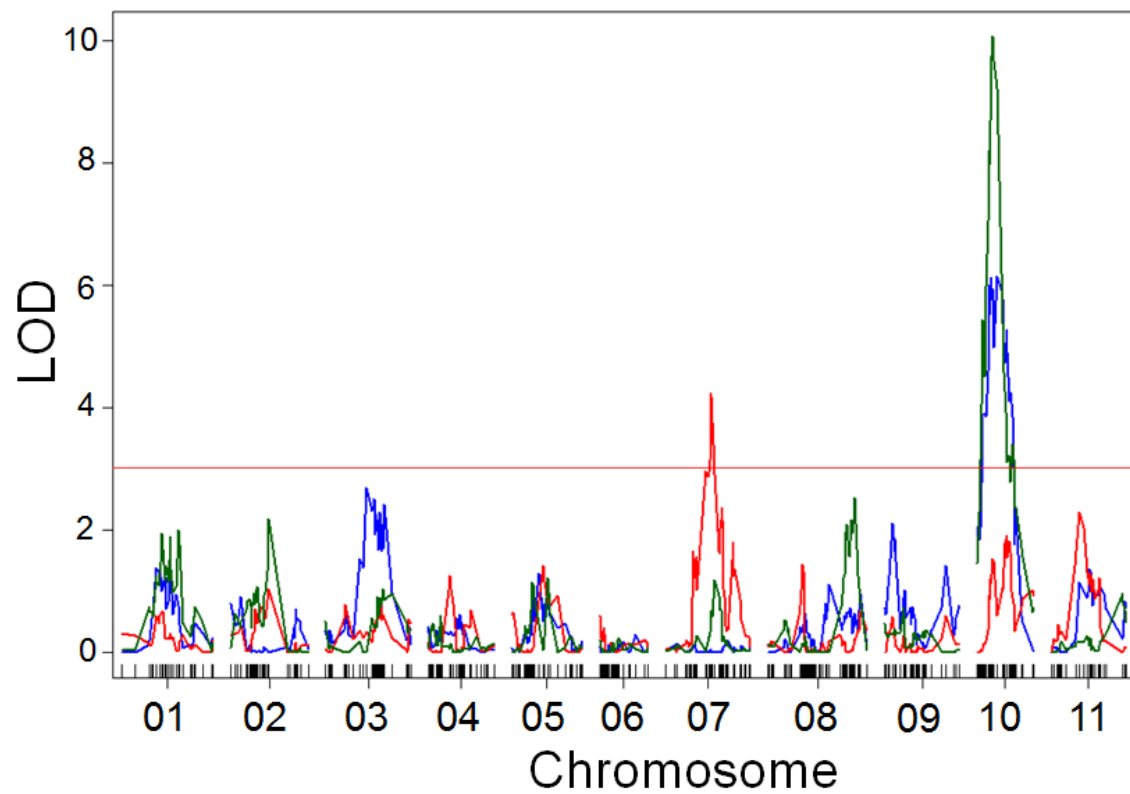


Figure S6. QTLs related to emergence rate. Robustness of germination and emergence has a profound effect on canopy growth. Emergence was low in 2017 (32%, blue) and 2019 (61%, green), but relatively high in 2018 (85%, red), and different QTLs controlled the trait between these years. The 95th percentile of LOD scores from 1000 randomized permutations of the data (LOD = 3.03) was used as a significance threshold.

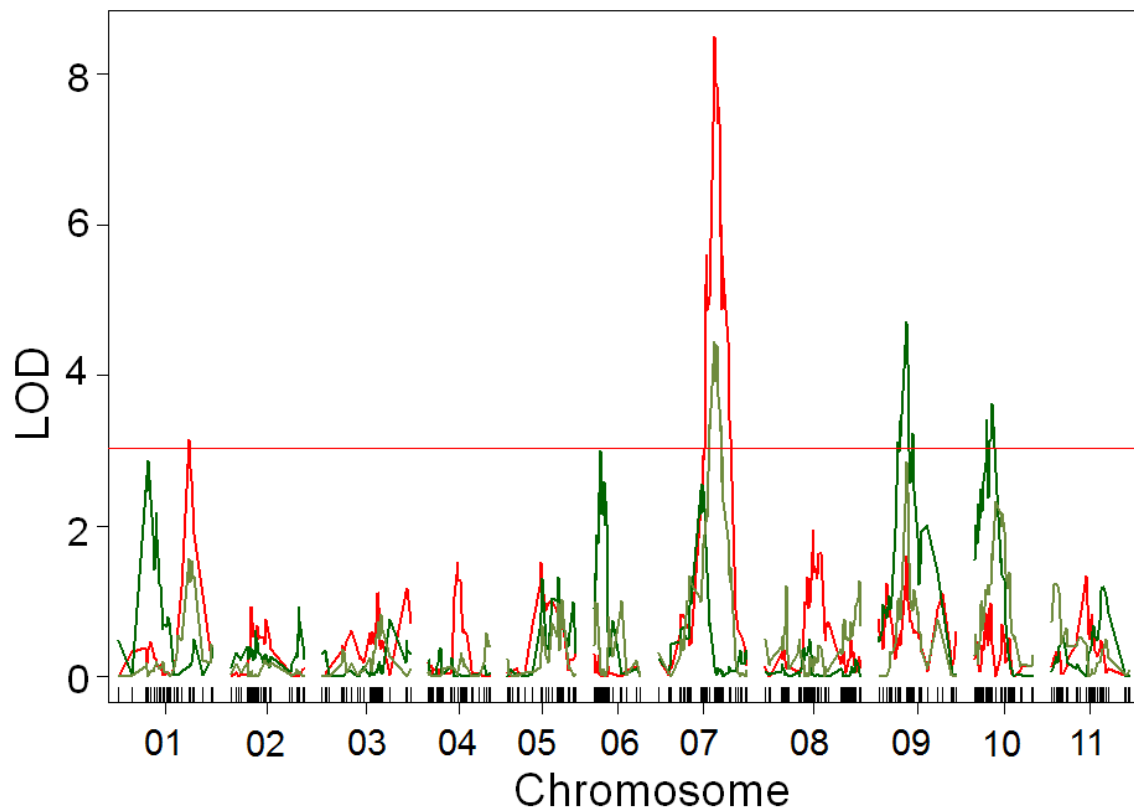


Figure S7. QTL mapping of hand-measured heights in the BxO population. At 42 DAP in 2018 (red), a major peak on Pv07 was evident. At 42 DAP in 2019 (dark green), several smaller QTLs were related to the trait, but by 63 DAP (light green), the Pv07 QTL had become significant as plants began to lodge. Results were based on data without correction for augmented design. The 95th percentile of LOD scores from 1000 randomized permutations of the data (LOD = 3.03) was used as a significance threshold.

Table S1. Positions of SNPs significantly associated with traits through GWAS.

Trait	Year	Most Significant SNP	Chromosome	Position	LOD, most significant SNP
Canopy height, hand-measured 42 DAP	2017	S01_447278	Pv01	44777278	7.03
Canopy height, hand-measured 42 DAP	2018	S07_34462447	Pv07	34462447	6.29
Canopy height, hand-measured 42 DAP	2018	S08_1316948	Pv08	1316948	7.14
Canopy height, drone-measured 42 DAP	2017	S03_13349070	Pv03	13349070	6.62
Canopy height, drone-measured 42 DAP	2017	S05_30689797	Pv05	30689797	6.99
Canopy height, drone-measured 42 DAP	2018	S04_55103	Pv04	55103	6.39
Canopy height, drone-measured 42 DAP	2018	S08_1316948	Pv08	1316948	6.42
Canopy cover growth rate, emergence corrected by LOESS residuals	2016	S01_1177020	Pv01	1177020	7.01
Canopy cover growth rate, emergence corrected by LOESS residuals	2018	S07_34512442	Pv07	34512442	9.08

Table S2. A comparison of early-season growth between Black Nightfall (BN) and Orca.

Trait	Year	Mean (BN)	Mean (Orca)	SD (BN)	SD (Orca)	p-Value (two-Tailed t-Test)	Significance
Emergence	2016	44.83	41.33	12.90	11.59	0.66	ns
Emergence	2017	26.38	12.75	6.39	7.07	0	**
Emergence	2018	159.63	109.88	6.36	19.19	0	***
Emergence	2019	84.08	57.17	14.76	10.69	0	***
Canopy growth rate per plot (cm ² plot ⁻¹ day ⁻¹)	2016	480.43	281.91	135.82	52.29	0.01	**
Canopy growth rate per plot (cm ² plot ⁻¹ day ⁻¹)	2017	994.19	213.31	174.33	89.61	0	***
Canopy growth rate per plot (cm ² plot ⁻¹ day ⁻¹)	2018	2807.86	1628.28	142.27	167.67	0	***
Canopy growth rate per plot (cm ² plot ⁻¹ day ⁻¹)	2019	2632.23	758.44	536.54	257.82	0	***
Canopy growth rate per plant (cm ² plant ⁻¹ day ⁻¹)	2016	10.91	7.57	1.58	2.89	0.047	*
Canopy growth rate per plant (cm ² plant ⁻¹ day ⁻¹)	2017	38.71	18.47	7.67	5.62	0	***
Canopy growth rate per plant (cm ² plant ⁻¹ day ⁻¹)	2018	17.60	15.26	0.78	2.96	0.06	ns
Canopy growth rate per plant (cm ² plant ⁻¹ day ⁻¹)	2019	31.73	13.26	5.80	3.67	0	***
Drone-measured canopy height 42 DAP (cm)	2016	13.1	10.0	4.6	2.7	0.19	ns
Drone-measured canopy height 42 DAP (cm)	2017	30.2	9.2	6.2	3.4	0	***
Drone-measured canopy height 42 DAP (cm)	2018	45.4	36.2	3.0	3.0	0	***
Drone-measured canopy height 42 DAP (cm)	2019	45.0	23.5	3.1	5.5	0	***
Hand-measured canopy height 42 DAP (cm)	2016	38.31	28.15	2.46	2.94	0	***
Hand-measured canopy height 42 DAP (cm)	2017	49.37	39.29	1.35	1.65	0	***
Hand-measured canopy height 42 DAP (cm)	2018	51.60	43.66	2.00	2.61	0	***
Hand-measured canopy height 42 DAP (cm)	2019	50.80	33.76	5.58	2.29	0	***

Table S3. Summary of QTLs significantly associated with growth rate in the BxO RI population. The most significant SNP(s) are listed along with the most significant SNP in the upstream and downstream directions. SNP coordinates are based on v2.1 of the *Phaseolus vulgaris Andean* genome reference sequence [61]. QTLs with identical positions between traits or years are indicated with asterisks in the chromosome column.

Trait	Year	Chromosome	Most Significant SNP	Position of most Significant SNP (bp, Genome v2.1)	LOD score, most Significant SNP	Upstream Flanking SNP	Position of Flanking SNP 1 (Mb, Genome v2.1)	LOD Score, Flanking SNP 1	Downstream Flanking SNP	Position of Flanking SNP 2 (Mb, Genome v2.1)	LOD Score, Flanking SNP 2
Emergence	2017	Pv10**	sc00119ln552178_356133_C_T_101986727	39124986	6.17	sc01321ln8683_4_2687_G_A_3_43229024	33609458	6.12	sc00156ln4907_45_316806_T_G_121001808	39812966	5.88
Emergence	2018	Pv07***	sc01522ln71313_49907_C_T_359138275, sc00659ln174637_29312_T_G_262099636	26581201, 26781502	4.25	sc00667ln1724_07_43926_G_A_263503992	25530277	3.15	sc00403ln2613_24_207173_G_A_207343141	26871528	4.19
Emergence	2019	Pv10	sc02147ln44740_15412_C_T_394527222	35632623	10.06	sc00603ln1909_94_176505_G_A_252033814	35357895	9.73	sc00078ln6695_40_46230_G_T_76714253	36893960	9.71
Canopy height, hand-measured 42 DAP	2018	Pv01	sc00022ln1003704_280981_C_T_32782853	48773773	3.14	sc01259ln9094_3_48696_C_T_337774864	47084408	1.19	sc00022ln1003_704_178718_A_G_32680590	48872687	3.06
Canopy height, hand-measured 42 DAP	2018	Pv07	sc00262ln351368_226896_C_T_164426117	32298702	8.5	sc01434ln7822_2_42548_A_C_352565471	32135594	8.15	sc00394ln2663_95_179893_C_A_204933545	32612675	8.36
Canopy height, hand-measured 42 DAP	2019	Pv09	sc00105ln590179_378162_T_G_94032280, sc00105ln590179_432554_A_G_94086672	17007673, 16953589	4.71	sc00080ln6582_50_291062_G_A_78288301	14192463	3.18	sc00063ln7046_77_263799_C_T_66628438	17719599	4.67
Canopy height, hand-measured 42 DAP	2019	Pv10	sc01142ln101735_70111_C_A_326510153, sc00633ln181418_21828_T_C_257467034	37228017, 37683218	3.63	sc00078ln6695_40_46230_G_T_76714253	36893960	3.63	sc00119ln5521_78_356133_C_T_101986727	39124986	2.72
Canopy height, hand-measured 63 DAP	2019	Pv07	sc01434ln78222_42548_A_C_352565471	32135594	4.44	sc00138ln5101_94_187113_A_C_111872296	30152459	3.35	sc00262ln3513_68_226896_C_T_164426117	32298702	4.44
Canopy height, drone-measured 42 DAP	2017	Pv09	sc00016ln1258381_85213_A_C_25771824	8427110	3.85	sc01015ln1165_54_82418_G_A_312723529	6088874	2.04	sc00042ln8192_84_180429_C_T_50792076	10109240	3.5
Canopy height, drone-measured 42 DAP	2017	Pv10	sc00267ln345535_21418_A_G_165965167, sc00794ln147497_57984_G_T_283720856	8184240, 8060803	5.73	sc04617ln9320_7677_T_C_45_0621006	5625057	4.52	sc01197ln9668_9_83817_G_A_331981619	9179745	5.76
Canopy height, drone-measured 42 DAP	2018	Pv09*	sc00105ln590179_378162_T_G_94032280, sc00105ln590179_432554_A_G_94086672	17007673, 16953589	3.63	sc00080ln6582_50_129523_C_T_78126762	14034332	2.65	sc00063ln7046_77_337006_T_C_66701645	17650074	3.34

Canopy height, drone-measured 42 DAP	2019	Pv09*	sc00105ln590179_378162_ T_G_94032280, sc00105ln590179_432554_ A_G_94086672	17007673, 16953589	7.44	sc00324ln3073 18_256674_A_G_184899333	13555560	4.6	sc00105ln5901 79_155124_C_ A_93809242	17226788	6.93
Canopy height, drone-measured 42 DAP	2019	Pv10**	sc00119ln552178_356133_ C_T_101986727	39124986	4.51	sc00078ln6695 40_46230_G_T_76714253	36893960	3.13	sc00156ln4907 45_316806_T_ G_121001808	39812966	3.18
Canopy cover growth rate, emergence corrected by Loess residuals	2017	Pv06	sc00162ln482802_46418_ G_A_123659537	19950405	3.28	sc00534ln2099 32_154675_C_ A_238084299	19359174	2.86	sc00827ln1420 80_1193_C_T_ 288452244	20003376	3.24
Canopy cover growth rate, emergence corrected by Loess residuals	2018	Pv06	sc00630ln182007_6318_ T_ C_256906010	17062325	3.8	sc00734ln1580 67_119101_A_ G_274625952	16591001	3.78	sc01288ln8860 8_79400_A_G_ 340410560	17688533	3.74
Canopy cover growth rate, emergence corrected by Loess residuals	2019	Pv07***	sc01522ln71313_49907_ C_ T_359138275, sc00659ln174637_29312_ T_G_262099636	26581201, 26781502	7.32	sc03437ln1968 0_9381_G_A_4_ 33942786	22404289	7.23	sc00403ln2613 24_207173_G_ A_207343141	26871528	7.25
Canopy cover growth rate, emergence corrected by Loess residuals	2019	Pv09*	sc00105ln590179_378162_ T_G_94032280, sc00105ln590179_432554_ A_G_94086672	17007673, 16953589	3.06	sc00080ln6582 50_229923_A_ C_78227162	14130721	2.57	sc00105ln5901 79_155124_C_ A_93809242	17226788	2.94