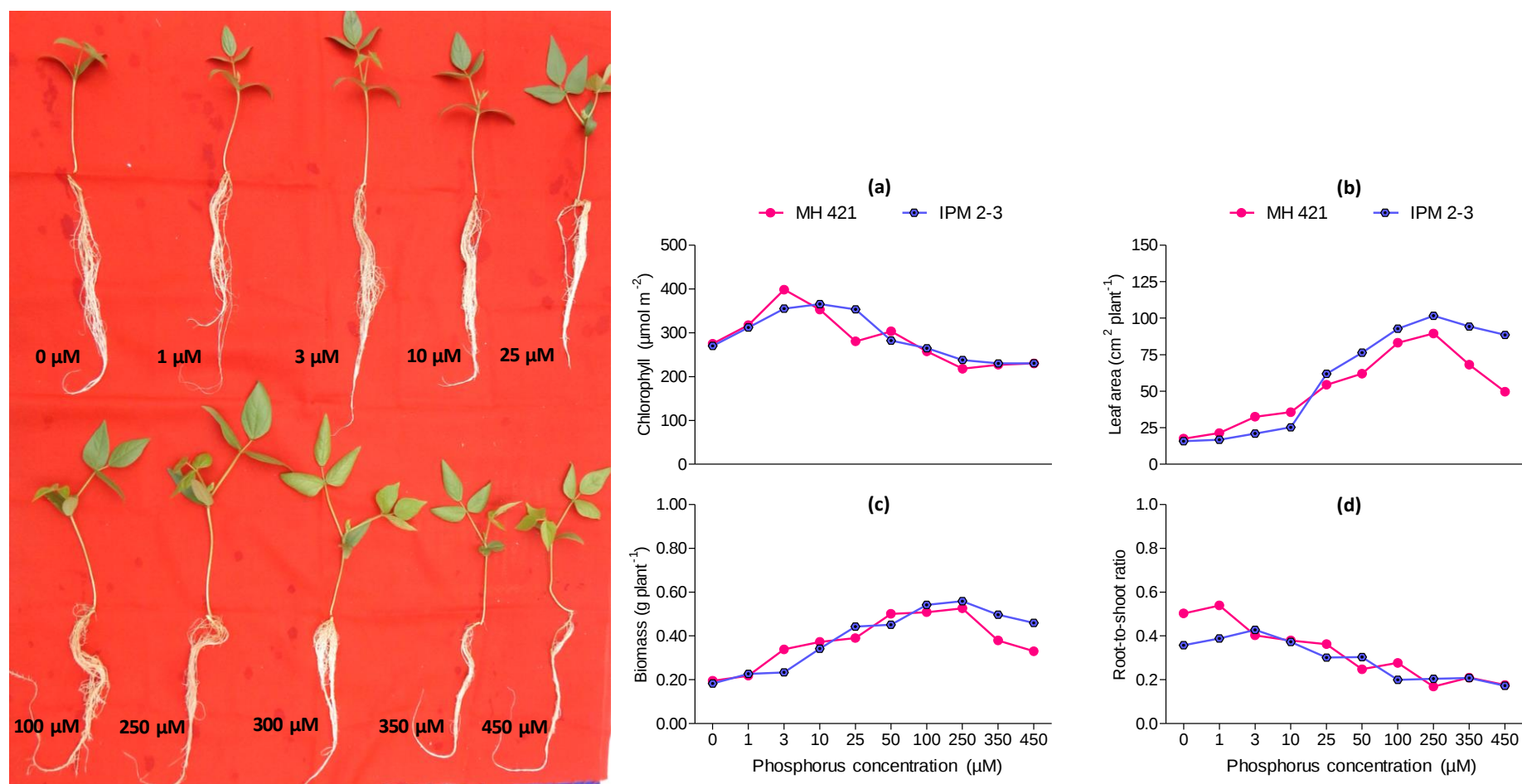
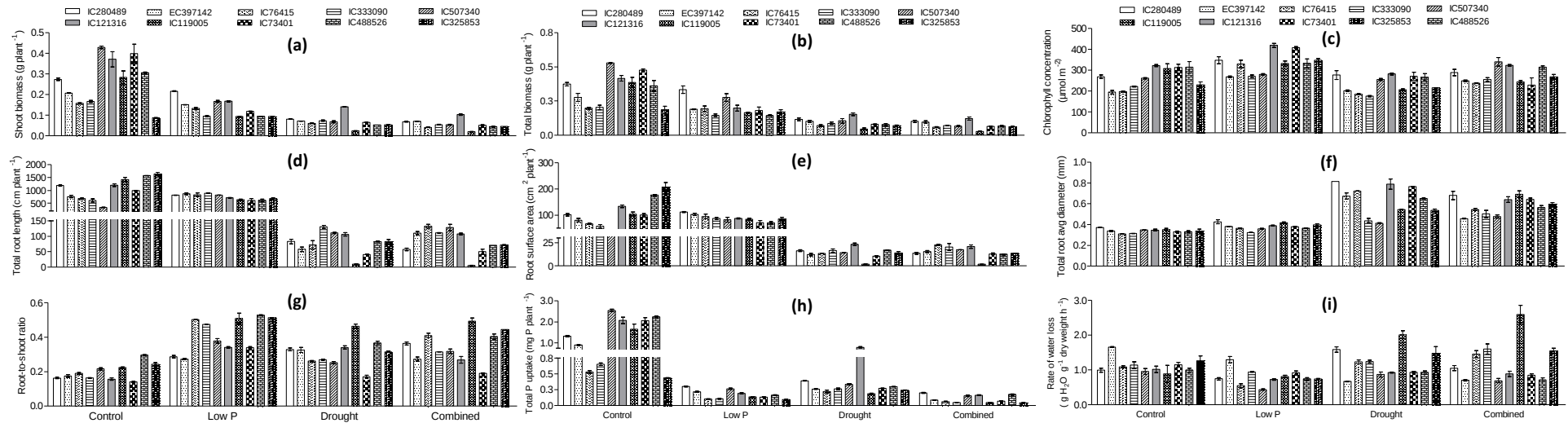




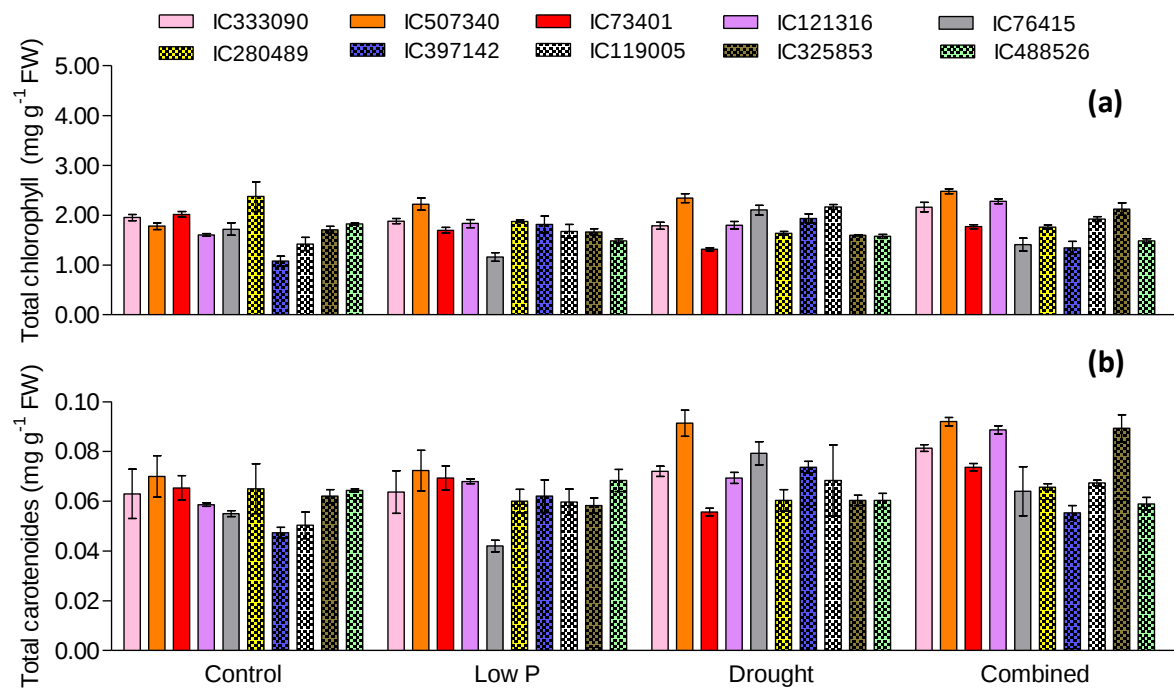
Supplementary Figure 1. (a) Experimental layout in the Issapur Farm, NBPGR, New Delhi with 1232 diverse mung bean accessions, (b) accession showing mid-day wilting, and (c) accession tolerant to mid-day wilting.



Supplementary Figure 2. Growth of mungbean seedlings in hydroponics at different phosphorus concentration to identify the optimum and low P levels. Growth traits such as (a) total chlorophyll, (b) leaf area, (c) total dry weight and (d) root-to-shoot ratio were recorded on 21 days old seedlings in two accessions, MH 421 and IPM 2-3.



Supplementary Figure 4. Actual performance (absolute values) of ten mungbean accessions selected from hydroponics experiment with respect to (a) shoot biomass, (b) total biomass, (c) chlorophyll concentration, (d) total root length, (e) root surface area, (f) root average diameter, (g) root-to-shoot ratio, (h) total P uptake, (i) rate of water loss at control, low P, drought and combined stress conditions. The tolerant (bars 1 to 6) and sensitive (bars 7 to 10) mungbean accessions were identified based on their response to different stresses as mentioned in Table 1.



Supplementary Figure 5. Effect of low P, drought and combined stress on concentration of (a) total chlorophyll, and (b) carotenoid in 10 mungbean accessions. 1-5 and 6-10 represents tolerant and sensitive accessions respectively. Error bars indicate mean $\pm$ SEM.

Supplementary Table 1. Passport data of 100 diverse mungbean accessions grown in hydroponics culture to screen for low phosphorus and drought stress tolerance

S. No.	Accession ID	Alternate ID	Biological Status	Collection Date	State	Country
1	EC398916	VC 6144(47-28-2)	Local collection	30-06-1996		Thailand
2	IC314606	PLM-0393	Local collection	01/03/2000	Punjab	India
3	EC398907	VC 6173B-14	Local collection	12-02-1991		Thailand
4	EC398414					Unknown
5	IC507276	PLM-76	Local collection		Bihar	India
6	IC553601	Pant Mung-6	Released variety	30/07/2007	Uttarakhand	India
7	IC417871	-	Local collection	-	Unknown	India
8	EC396156	-	Local collection			Unknown
9	IC507418	PLM-488				India
10	IC489004	PLM-417	Local collection	-	Punjab	India
11	IC257571	RM4/U48/DP-93	Local collection	14/12/1999	Odisha	India
12	IC401586	OBGG-52	Released variety	31/05/2003	Odisha	India
13	IC148401	STV-2631	Primitive cultivar	06/09/1992	Telangana	India
14	IC305222	-	Local collection	-	Unknown	India
15	IC565301	RMG977	Elite line	-	Unknown	India
16	IC73112	Sonali (B1)	Released variety	14/04/1982	Odisha	India
17	IC148442	STV-2717	Primitive cultivar	09/09/1992	Telangana	India
18	IC280489	NKG-24	Local collection	16/12/2000	Odisha	India
19	EC398131	-				Unknown
20	EC398899	VC 3960-89	Local collection	11-01-1991		Thailand
21	IC76468	M-647	Local collection	31/12/1967	Delhi	India
22	IC489015	PLM-649	Local collection	-	Gujarat	India
23	IC488904	PLM-634	Local collection		Punjab	India
24	IC507527	PLM-933	Local collection		Gujrat	India
25	IC507331	PLM-212	Local collection		Bihar	India
26	IC488951	PLM-327	Local collection		Bihar	India
27	IC76414	M-538	Local collection	31/12/2004	Uttar Pradesh	India
28	IC76370	M-461	Local collection	31/12/1985	Rajasthan	India
29	IC507321	PLM-188	Local collection		Uttar Pradesh	India
30	EC397142		Local collection	30/6/1996		Unknown
31	IC507497	PLM-789	Local collection	-	Rajasthan	India
32	EC397141	-	Landrace	30/6/1996		Unknown
33	IC76466	M-643	Local collection	31/12/1967	Delhi	India
34	IC507320	PLM-187	Local collection		Bihar	India
35	IC285532	-	Local collection	-	Unknown	India
36	IC357035	-	Local collection	-	Unknown	India
37	IC252008	73	Local collection	16/08/1999	Unknown	India
38	IC488813	PLM-510	Local collection			India

39	IC507504	PLM-811	Local collection		Rajasthan	India
40	IC76499	M-703	Local collection	31/12/1967	Delhi	India
41	IC305250	-	Local collection	-	Unknown	India
42	IC507526	PLM-919	Local collection		Gujrat	India
43	IC76415	M-539	Local collection	31/12/2005	Delhi	India
44	IC76451	M-613	Local collection	31/12/1967	Delhi	India
45	IC507525	PLM-907	Local collection	03-01-2000	Gujrat	India
46	IC507483	PLM-746	Local collection		Gujrat	India
47	IC76491	M-687	Local collection		Delhi	India
48	IC333090	BM-4	Elite line	03/11/2001	Madhya Pradesh	India
49	IC488582	T-2	Elite line	-	Unknown	India
50	IC507340	PLM-232	Local collection		Bihar	India
51	IC76346	PLM-420	Local collection			India
52	IC507376	PLM-314	Local collection		Bihar	India
53	IC548275	WGG 37	Released variety	01/01/1997	Telangana	India
54	IC398746	AKP-12/14	Local collection	23/04/2003	Bihar	India
55	IC282110	CN-9002	Elite line	23/10/2000	Telangana	India
56	IC76422	M-553	Local collection	31/12/2010	Punjab	India
57	IC488849	PLM-333	Local collection		Uttar Pradesh	India
58	IC488966	PLM-754	Local collection	03-01-2000	Rajasthan	India
59	IC489093	PLM-719	Local collection		Gujrat	India
60	IC488808	PLM-503	Local collection	-	Unknown	India
61	IC118993	SD-2/197	Local collection	-	Maharashtra	India
62	IC121249	PLM-614	Local collection			India
63	EC398949	VC 6173C	Local collection	30-09-1996		Thailand
64	EC398880	VC 6148(50-12)	Local collection	30/9/1996		Thailand
65	EC398937	VC 6173B-14	Local collection	30-06-1996		Thailand
66	EC398886	VC 6173B-13	Local collection	30/9/1996		Thailand
67	IC119005	ML-9	Elite line	-	Maharashtra	India
68	IC754464					India
69	IC405261	Asha	Genetic stock	18/10/2003	Haryana	India
70	IC507299	PLM-126	Local collection		Bihar	India
71	IC305249		Local collection			India
72	IC488619	PLM-462	Local collection			India
73	IC332327	U-53/VR/158	Local collection	11/11/2001	Madhya Pradesh	India
74	IC314512	PLM-268	Local collection		Madhya Pradesh	India
75	IC249567	NS - 6728	Local collection	16/03/1999	Telangana	India
76	IC73401	DMS-43	Local collection	31/12/1985	Bihar	India
77	IC121316	PS-16	Released Variety			India
78	EC396413	VC - 3004 A	Local collection	16-06-1988		Taiwan
79	IC488875	PLM-376	Local collection		Jammu & Kashmir	India
80	EC314285	VC-1137A	Local collection	02-12-1991		TAIWAN
81	IC11283	PI 363274	Local collection	25/11/1964	Gujarat	India
82	IC488526	EARLY BARSATI	Released variety		Madhya Pradesh	India
83	IC507379	PLM-318	Local collection	-	Unknown	India

84	IC119018	PDM-84-139	Elite line	-	Maharashtra	India
85	IC325853	KCM/BR-137	Local collection	13/10/2001	Rajasthan	India
86	IC553566	MH-215 (Sattya)	Released variety	26/07/2007	Haryana	India
87	IC315045	PLM-0592	Local collection	01/03/2000	Telangana	India
88	IC76581	M-938	Local collection	31/12/1967	Delhi	India
89	IC507296	PLM-123	Local collection		Uttar Pradesh	India
90	IC507319	PLM-185	Local collection		Madhya Pradesh	India
91	IC590082	MH-421	Released variety	2014*	Haryana	India
92	IC623704	PDM-139	Released variety	2001*	Uttar Pradesh	India
93	IC623821	SML-668	Released variety	2002*	Punjab	India
94	IC573083	IPM-02-03	Released variety	2009*	Uttar Pradesh	India
95	IC584699	IPM-02-14	Released variety	2010*	Uttar Pradesh	India
96	IC415097	MEHA (IPM 99-125)	Released variety	2004*	Uttar Pradesh	India
97	HUM-1	Malviya Jyoti	Released variety	1999*	Uttar Pradesh	India
98	IC623705	PUSA VISHAL	Released variety	2000*	Delhi	India
99	IC393792	GANGA-8	Released variety	2001*	Rajasthan	India
100	IC512343	ML-818	Released variety	2001*	Punjab	India

*Year of release for varieties

Supplementary Table 2. The significance of sources of variability for accessions (G, 100 accessions), phosphorus (P, 2 levels), moisture (W, 2 levels) and their interaction effects on growth, water balance and root traits of mungbean accessions grown in hydroponics. *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$, NS non-significant.

Traits	Significance of sources of variability						
	P	W	G	PXW	PXG	WXG	PXWXG
Chlorophyll concentration	3086***	1710***	46.5***	436.5***	8.98***	13.8***	6.88***
Rate of water loss (gg ⁻¹ h ⁻¹)	699.5***	8.7**	16.9***	393.4***	3.8***	10.5***	4.1***
Moisture retention capacity (%)	79.9***	34.3***	56.4***	60.4***	11.3***	35.5***	7.6***
Excised leaf weight loss_30	6.3*	3.3NS	24.7***	144.6***	9.7***	18.4***	4.1***
Excised leaf weight loss_90	44.6***	15.1***	30.9***	3.7NS	6.1***	12.5***	6***
Excised leaf weight loss_140	38.5***	483.1***	40.7***	4.6*	7.2***	9.2***	6.2***
Shoot dry weight (g)	6461***	22745***	124.7***	3868***	24.8***	46.9***	20.6***
Root dry weight (g)	8.5**	14262***	87.7***	39.62***	9.8***	31.6***	10.46***
Total dry weight (g)	4323***	23497***	127.4***	2357***	20.7***	47***	18***
Root-shoot ratio	7937***	13.9***	58.99***	3967***	17.8***	30.3***	14.7***
Plant P concentration (%)	204085***	775.6***	207.1***	9504***	121.8***	27.6***	23***
Total P uptake (mg plant ⁻¹)	26327***	15636***	105***	11919***	74.4***	48.5***	43.2***
Total root length (cm)	1506***	30597***	46.63***	1472***	15.8***	39***	15.1***
Root surface area (cm ²)	819***	28184***	67.3***	741***	16.6***	49.8***	16.6***
Root volume (cm ³)	226***	14628***	68.88***	92.55***	11.9***	34.0***	10.94***
Root average diameter (mm)	23.8***	10490***	35.4***	490.7***	8.2***	24.9***	8.7***
Number of root tips	746.3***	30855***	59.7***	808.7***	30.6***	42.3***	29.6***

Supplementary Table 3. The PCA ranking values derived from principal components (PC) 1 to 4 using 14 physiological traits of mungbean under low P, drought and combined stresses.

S. No.	Accessions	Low P	Drought	Combined stress
1	EC398916	30.93	94.31	65.01
2	IC314606	85.92	95.00	74.76
3	EC398907	62.18	60.50	63.64
4	EC398414	33.46	87.90	71.99
5	IC507276	54.50	93.14	67.48
6	IC553601	75.10	74.24	70.00
7	IC417871	66.30	79.31	67.72
8	EC396156	76.18	87.86	61.91
9	IC507418	70.14	95.64	65.05
10	IC489004	68.25	74.36	64.25
11	IC257571	143.06	95.08	68.76
12	IC401586	77.75	91.38	68.17
13	IC148401	75.37	78.49	60.76
14	IC305222	89.53	94.85	66.36
15	IC565301	85.55	72.12	61.04
16	IC73112	68.19	70.46	48.69
17	IC148442	114.68	88.84	69.78
18	IC280489	87.78	95.33	79.89
19	EC398131	90.77	84.07	62.44
20	EC398899	68.60	78.82	66.18
21	IC76468	86.29	86.78	82.40
22	IC489015	58.45	88.64	80.97
23	IC488904	49.74	77.34	60.81
24	IC507527	110.11	93.40	75.11
25	IC507331	54.90	85.48	69.17
26	IC488951	45.72	86.06	75.44
27	IC76414	62.21	110.93	79.07
28	IC76370	60.14	66.79	71.21
29	IC507321	72.47	103.62	82.26
30	EC397142	96.80	95.15	77.95
31	IC507497	69.40	82.69	67.72
32	EC397141	89.42	97.94	77.30
33	IC76466	65.64	77.19	78.95
34	IC507320	74.66	89.90	74.15
35	IC285532	113.98	77.03	65.61
36	IC357035	53.98	70.28	71.97
37	IC252008	41.42	75.80	66.71
38	IC488813	99.97	82.79	70.97
39	IC507504	100.88	78.02	60.51
40	IC76499	47.22	87.89	80.66
41	IC305250	41.15	70.66	69.09
42	IC507526	38.12	67.55	73.40

43	IC76415	101.95	92.50	84.97
44	IC76451	60.23	72.83	63.14
45	IC507525	55.71	76.73	72.87
46	IC507483	52.05	102.25	72.28
47	IC76491	68.23	80.63	67.03
48	IC333090	87.51	88.66	84.49
49	IC488582	73.52	69.55	58.49
50	IC507340	157.10	94.57	96.00
51	IC76346	54.94	69.39	62.53
52	IC507376	90.14	85.13	70.98
53	IC548275	73.27	88.65	73.21
54	IC398746	91.70	71.59	70.68
55	IC282110	78.35	79.81	68.41
56	IC76422	35.86	100.63	85.80
57	IC488849	33.06	83.44	73.79
58	IC488966	130.61	92.36	69.21
59	IC489093	49.79	72.38	61.15
60	IC488808	9.22	66.78	76.27
61	IC118993	14.81	57.17	65.94
62	IC121249	43.03	73.15	63.63
63	EC398949	86.88	92.43	73.60
64	EC398880	52.28	69.54	61.24
65	EC398937	67.96	81.81	80.58
66	EC398886	52.07	88.14	77.21
67	IC119005	40.06	62.74	60.92
68	IC754464	45.39	62.65	70.52
69	IC405261	39.45	75.99	77.03
70	IC507299	55.02	85.90	73.89
71	IC305249	108.97	85.59	84.37
72	IC488619	75.09	78.05	67.62
73	IC332327	51.95	76.95	70.94
74	IC314512	65.25	101.13	73.13
75	IC249567	57.00	80.92	71.71
76	IC73401	34.27	72.08	59.02
77	IC121316	41.76	108.20	78.30
78	EC396413	38.41	78.14	77.37
79	IC488875	40.97	72.29	70.19
80	EC314285	41.46	67.27	64.65
81	IC11283	46.95	87.58	72.99
82	IC488526	28.94	68.96	62.14
83	IC507379	44.74	77.44	66.40
84	IC119018	31.56	71.02	69.79
85	IC325853	34.34	60.32	64.11
86	IC553566	51.17	70.23	67.07
87	IC315045	44.96	82.64	79.87
88	IC76581	12.64	76.55	65.24
89	IC507296	25.77	70.30	57.34

90	IC507319	43.60	105.90	67.85
91	IC590082	19.86	69.72	62.97
92	IC623704	39.77	74.89	54.86
93	IC623821	27.33	69.76	76.57
94	IC573083	47.65	74.14	75.78
95	IC584699	25.75	79.77	66.36
96	IC415097	27.56	72.91	64.11
97	HUM-1	29.74	82.03	72.90
98	IC623705	67.96	82.51	79.11
99	IC393792	52.45	70.28	58.22
100	IC512343	74.84	73.00	89.63

Supplementary Table 4. The significance of sources of variability for accessions (G, 10), phosphorus (P, 2 levels), moisture (W, 2 levels) and their interaction effects on growth and yield traits of mungbean accessions grown in soil. *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$, NS- not significant

Traits	Significance of sources of variability						
	P	W	G	PXW	PXG	WXG	PXWXG
Membrane stability index	574.2***	1095.8***	20.6***	0.4NS	21.9***	17.8***	27.9***
Relative water content	89.5**	273.3***	26.5***	5.5*	3**	5.5***	2.9**
Dry weight plant ⁻¹	668.7***	1399***	698***	64.7**	18.9***	19.1***	8.5***
Seed P concentration (%)	712.5***	415.1***	145.5***	20.8***	61.7***	19.2***	15.6***
Shoot P concentration (%)	472.8***	110.9***	77.7***	63.9***	66.9***	18.2***	8.9***
Seed P uptake (mg/plant)	11055.4***	20858.6***	1475.5***	2196.1***	146.7***	356.4***	181***
Shoot P uptake (mg/plant)	2418.6***	2101.2***	1563.3***	186.3***	150.5***	74.4***	18.1***
P use efficiency for seed yield	23.3***	1671.3***	412.9***	12.1***	192.6***	412.2***	97.8***
P use efficiency for dry biomass	1443.9***	695.9***	165.1***	25.1***	95.9***	49.2***	16***
Number of pods plant ⁻¹	101.9***	163.7***	45.2***	8.2**	2.8**	3**	2.5**
Pod weight (g plant ⁻¹)	174.2***	493***	108***	20.6***	7.4***	6.3***	6.8***
Number of seed pod ⁻¹	4.5***	86.1*	35.7***	0.09NS	7.9***	14.4***	3**
Seed yield (g plant ⁻¹)	489***	1170***	138.5***	134***	8.7***	26.4***	9.9***
100-seed weight (g)	16.1***	20.9***	114.6***	46.4***	28.5***	19.9***	9.5***
Harvest index (%)	82.7***	244.4***	28.3***	11.3***	3.9***	24.9***	6.9***
P harvest index	763.9***	2798.9***	302.5***	0.30NS	62.6***	300.9***	110.6***

Supplementary Table 5. The significance of sources of variability for accessions (G, 10), phosphorus (P, 2 levels), moisture (W, 2 levels) and their interaction effects on photosynthetic pigments and gas exchange traits of mungbean accessions grown in soil. *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$, NS- not significant

Traits	Significance of sources of variability						
	P	W	G	PXW	PXG	WXG	PXWXG
Total chlorophyll (Chl)	0.3NS	14.1***	18.7***	1.2NS	9.8***	11***	11.8***
Carotenoids (Car)	4.2*	37.3***	6.4***	0.4***	2.5***	3.5***	2.7***
Transpiration rate	1734***	12496***	168***	1.1NS	44.76***	98.1***	19.2***
Stomatal conductance	3866***	14136***	343***	40.9***	164.5***	133.3***	72.6***
Rate of photosynthesis	1065***	6566.6***	126.1***	71.4***	28.5***	57***	27.8***
Instantaneous water use efficiency	133.5***	524.3***	42.2***	139***	29.2***	57.8***	28.1***

Supplementary Table 6. The significance of sources of variability for accessions (G, 10), phosphorus (P, 2 levels), moisture (W, 2 levels) and their interaction effect on root organic acid exudation of mungbean accessions grown in hydroponics. *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$, NS, not significant

Trait	Significance of sources of variability						
	P	W	G	PXW	PXG	WXG	PXWXG
Oxalate	655.4***	49.7***	81.6***	49.7***	81.6***	19.1***	19.1***
Citrate	226.6***	545.5***	179.6***	2184.5***	290.7***	295.4***	191.7***
Maleate	48.8***	6.1*	85.2***	667.4***	126.5***	122.6***	106.5***
α -Ketoglutarate	897.2***	1364.2***	136.4***	1311.7***	258.4***	66.8***	54.7***
Pyruvate	1048***	1568***	323.2***	2556***	201.8***	206.1***	152.1***
Malonate	205.7***	62.7***	59.6***	0.01NS	36.6***	24***	56.8***
Malate	556.2***	209.1***	68.1***	251.9***	71***	108.2***	104***
Lactate	75.4***	45.2***	28.3***	325.5***	22.5***	26.5***	34.4***
Succinate	579.3***	30***	37***	102***	27.5***	9.4***	15.1***
Acetate	552.8***	350.7***	41.6***	1554.4***	79.46***	115.8***	65***
Fumarate	0.6NS	4.6*	30.2***	1390***	20.8***	34.2***	33.1***
Total organic acid	0.3NS	275.2***	73.5***	2298***	129.5***	67.1***	165.2***