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Phosphorus Response and Amino Acid Composition of Different Green Gram (*Vigna radiata* L.) Genotypes from Myanmar

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Abstract

Mungbean or green gram (*Vigna radiata* L.) is an important component of rice-based cropping systems in Myanmar, where grain yields of around 800 kg ha^{-1} are much below its yield potential of 3000 kg ha^{-1}. The reasons for this shortfall are as under-investigated as is the genotype-specific response of this crop to phosphorus (P) application, which is critically low in many Myanmar soils, and the genetic variation in grain quality. For green gram quality, the concentration of lysine, an essential amino acid is particularly important given its scarcity in many cereal-based diets of Southeast Asia. The purpose of this study therefore was to investigate the effects of P application on the root and shoot growth, yield and its components for a range of green gram varieties, and to analyse the protein concentration and amino acid composition in green gram seed of different origins. To this end from 2001 to 2003, field experiments were conducted under rain-fed conditions in Yezin and Nyaung Oo. Fifteen landraces and five introduced green gram cultivars were grown at two levels of P (0 and 15 kg ha^{-1}). There were large genotypic differences in P effects and a significant interaction between green gram genotypes and P for shoot and root growth. An unexpected benefit of P application was a reduction of pest and plant virus infestation in the field. Significant genotypic differences in the amino acid profile of seeds were also observed. The results indicate the potential for breeding efforts to increase seed yield and protein quality in green gram.

Keywords: Landraces, lysine, mungbean, protein quality

1 Introduction

Since prehistoric times, green gram (*Vigna radiata* L.) has been an important short-season grain legume and staple diet of humans and livestock throughout S.E. Asia (Thomas *et al.*, 2004). Grown widely in this region, green gram is one of the least researched and under-exploited major grain legumes (Lawn and Ahn, 1985). In Myanmar, throughout the year, this crop is an important component of the country's rice-based

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cropping systems, where legumes cover about 8.5% of the total cultivated area and in combination with chickpea (*Cicer arietinum* L.), lima bean (*Phaseolus lunatus* L.), black gram (*Vigna mungo* L.), pigeonpea (*Cajanus cajan* L.) and lablab bean (*Lablab purpureus* L.) it accounts for 80% of all harvested grain legumes (THAUNG, 1989). In recent years Myanmar has replaced Australia as the world's second largest exporter of grain legumes after Canada (MYANMAR TIMES, 2002). The main buyers of Myanmar's grain legumes are India and Japan, with new markets emerging in Jordan and Pakistan. Among the best selling Myanmar grain legumes on export markets are black gram, green gram and pigeonpea. For green gram, this demand is partly rooted in its seed protein ranging between 19 and 29% and in its high lysine concentration which is the major limiting amino acid in cereal proteins for humans and monogastric animals (JOOD and SINGH, 2001). This is particularly true for populations in SE Asia with their reliance on rice-based diets. In the future, local demand and export opportunities for green gram may thus partly depend on its lysine concentrations. With current grain yields of around 800 kg ha^{-1} green gram in Myanmar is significantly below the reported yield potential (around 3000 kg ha^{-1}) and little is known about the reasons for this shortfall.

Since 1991 the Japan-Myanmar Seed Bank Project has collected traditional land races of green gram. However, so far this germplasm has not been evaluated for agronomic traits such as growth, yield, nutrient uptake and quality for human nutrition. Given the low on-farm yields of green gram in Myanmar and its importance in local diets, there may be considerable potential for an even increased use of this crop after proper breeding for heritable traits (ANISHETTY and MOSS, 1988). Exploiting the genetic diversity of plants for enhanced productivity in low fertility soils is an important goal of modern plant breeding (GOURLEY *et al.*, 1994) and genotypes with high phosphorus (P) use efficiency (with respect to both uptake and translocation) would be particularly valuable in Myanmar where mineral P fertilizers are hardly available and many soils are low in P (GUNAWARDENA *et al.*, 1992). The aims of this paper therefore were (i) to examine differences in growth response to P application among green gram varieties and (ii) to compare the amino acid composition in green gram seed of different origins.

2 Methodology

2.1 Site conditions and experimental setup

From 2001 to 2003 three field experiments were conducted under rainfed conditions at Yezin Agricultural University Farm (YAU, 19° 38'N latitude, 96° 50'E longitude, 102 m altitude, average total precipitation 1000 mm from May to October) and Nyaung Oo (21° 10'N latitude, 94° 54'E longitude, 70 m altitude, average total precipitation 450 mm from May to October) in Myanmar. The first experiment at YAU comprised 15 landraces and five introduced green gram cultivars grown with 0 and 15 kg P ha^{-1} applied as basal triple-super phosphate (TSP with 21% P) from 15th June to 30th September 2001 with 1169 mm rainfall (Table 1).

The soil properties (0-0.2 m depth) of the site were pH-water 5.6, 0.05 g total nitrogen (N) kg^{-1} soil and 6.8 mg Bray-1 P kg^{-1}. A split-plot design with three replications was used with P application as the mainplot factor and genotypes randomly attributed

Table 1: List of improved cultivars and landraces of green gram (*Vigna radiata* L.) tested for their growth response to phosphorus and for their amino acid composition in a field experiment in Myanmar, 2001.

Experiment/ Identifier		*Genotype*	*Accession number*	*Classification*	*Provenance*
1,2,3	(A)	V-3726	-	Improved	AVRDC*
1	(B)	Yezin-4	-	Improved	AVRDC
1,2,3	(C)	VC-5205A	-	Improved	AVRDC
1,2,3	(D)	Kanti	-	Improved	Bangladesh
1,2,3	(E)	Myakyemon	-	Improved	Kyemon Station
1,2	(F)	Yegyi-kangoo	004200	Landrace	Yegyi township
1	(G)	Myaung	004199	Landrace	Myanung township
1,2	(H)	Gangaw-7375	007375	Landrace	Gangaw township
1,2	(I)	Yinmarbin	004184	Landrace	Yinmarbin township
1,2	(J)	Gangaw-4187	004187	Landrace	Gangaw township
1,2,3	(K)	Pakhoku	007379	Landrace	Pakhoku township
1	(L)	Gangaw-7380	007380	Landrace	Gangaw township
1	(M)	Magwe	004198	Landrace	Magwe township
1	(N)	KhinOo	004201	Landrace	KhinOo township
1,2,3	(O)	Ayadaw	007354	Landrace	Ayadaw township
1,2	(P)	Kyemon	004192	Landrace	Kyemon township
1,2	(Q)	Thawatti	004185	Landrace	Thawatti township
1,2	(R)	Nyaunglaybin	004186	Landrace	Nyaunglaybin township
1,2	(S)	Mahling	004197	Landrace	Mahling township
1,2	(T)	Pauk	007377	Landrace	Pauk township

* Asian Vegetable Research and Development Centre

to subplots. Land preparation was done by tractor with one ploughing followed by two harrowings. Plant spacing was 0.45 m between and 0.10 m within rows with 10 plants per row. Fertilizers were band-placed at 2 cm soil depth and incorporated into the soil before sowing. Weeding was done by hand and pest control during the vegetative stage of the crop by two applications of the synthetic pyrethroide cypermethrin (26% active ingredient) at a rate of 7.5 l ha^{-1}. Total dry matter (TDM) as well as shoot and grain yield obtained from the experiment were subjected to analysis of variance. Amino acids in the seed were analysed using an amino acid analyser following the procedure of VDLUFA (1988).

In a second experiment conducted from end of June to early October 2002 at Nyaung Oo Research Farm eleven landraces (named Yegyi-kangoo, Gangaw-4187, Yinmarbin, Pakhoku, Ayadaw, Kyemon, Thawatti, Nyaunlaybin, Mahling, Pauk and Gangaw-7375) and four introduced green gram cultivars (V-3726, VC-5205A, Kanti and Myakyemon) were grown with 0 and 15 kg P ha^{-1} (applied as basal TSP) at 413 mm rainfall. Fertilizers were band-placed at 2 cm soil depth and incorporated into the soil before sowing. The 11×2 factorial experiment was arranged in a randomized complete block design (RCBD) with four replications. The site had a pH-water of 7.2, 0.02 g total N

kg^{-1} and 5.7 mg Bray-1 P kg^{-1}. Land preparation was done by tractor. Plant spacing was 0.45 m between and 0.10 m within rows with 5 m length. For the estimation of insect damage, representative leaves were selected and the 'technique of the four quarters' was used to estimate the relative area of holes in the leaves at flowering. Heavy pest infestation was found at harvesting. For the estimation of mungbean mosaic virus damage, the number of virus-diseased plants was recorded following a scoring key of 0 to 2 (0 = no symptoms, 1 = some mosaic, 2 = heavy mosaic symptoms with stunting and/or leaf rolling and/or mosaic) (James, 1971). No other diseases were detected. For measurements of root length density following the line intersection method of Tennant (1975) a total of ten samples at 0 to 0.2 m depth were taken in each plot of three of the four blocks. Samples were pooled at the plot level, transported to Yezin, washed and analysed.

In the third experiment from end of May to early October 2003 a subset of four introduced cultivars (V-3726, VC-5205A, Kanti and Myakyemon) and the two green gram landraces Pakhoku and Ayadaw were grown again with 0 and 15 kg P ha^{-1} as TSP at YAU with 727 mm rainfall. A factorial design with four complete blocks (replications) comprising twelve treatment combinations (plots) each was used. Root growth at flowering was measured by inserting an aluminium tube of 25 mm diameter five times per plot to 0-10 cm and 10-20 cm depth. Ink-stained roots (to ease counting) from the samples, pooled for each depth interval and plot, were used to determine root length density. Shoot growth of green gram was determined at each root sampling and analysed for N and P.

2.2 Pot experiment

Two of the improved cultivars, V-3726 and Yezin-4 tested in both field experiments at YAU and the most P responsive landraces, Ayadaw and Mahling were chosen for a pot experiment under controlled (greenhouse) conditions in Germany to examine possible varietal differences in N and P uptake. To this end TSP equivalent to 0 and 15 kg P ha^{-1} was mixed with 4 kg of the C-horizon of a P poor sandy soil from Bischhausen, Germany in 32 pots (4×2 factorial in a completely randomized design with 4 replicates) of 5 l volume. The soil's properties were pH-water of 7.8, 0.0015 g total N and 1.7 mg Olson-P kg^{-1} soil. For each green gram genotype four seeds of similar size were planted at a depth of 2 cm. Deionized water was applied daily to 10% w/w to account for evapotranspiration losses. No rhizobium inoculation was made. To avoid the effects of climate gradients on plant development, the pots were re-randomised every two days. Ten days after sowing (DAS) seedling were thinned to 1 plant per pot. All plants were harvested by 30th December 2001 when dry matter of roots and shoots (stems, pods and seeds) and the number of nodules per plant was determined. Total N was measured with a Macro-N-Analyser (Heraeus, Bremen, Germany). For P analysis shoot and seed samples were ashed for 4 hrs in a muffle furnace at 500 °C and the ash was dissolved in 1:30 (v/v) HCl. Phosphorus was determined colourimetrically (Hitachi U-2000 spectrophotometer). Stained roots from the samples were used for root length determination.

2.3 2.3 Data analysis

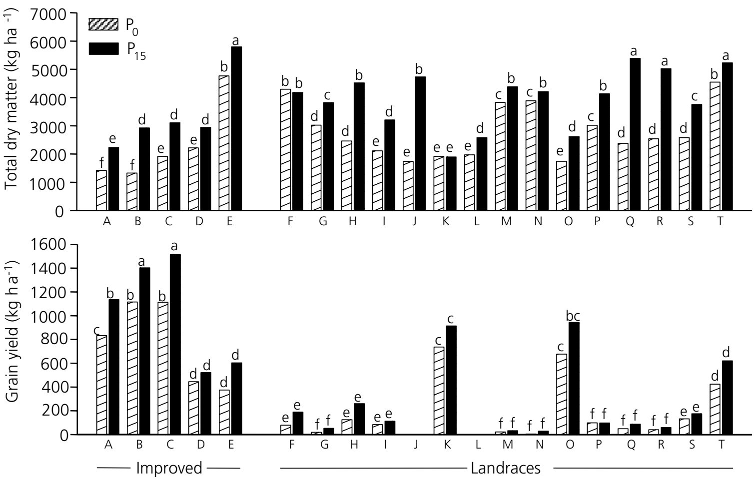
All data on yields and nutrient concentrations were subjected for each season separately to analysis of variance (ANOVA) using GENSTAT 5 (Lawes Agricultural Trust, 2000). Treatment means were separated using Fisher's protected $LSD_{0.05}$. Disease score data were also analyzed by F-tests, whereby given the typically lacking normal distribution of such data, F-values are only approximative.

3 Results

3.1 Field experiments at Yezin and Nyaung Oo

In 2001 and 2002, highly significant TDM and grain yield differences between green gram genotypes and significant, site-specific $\mathrm{P} \times$ genotype interactions were found for both parameters (Fig. 1 and 2). At Yezin across P levels the grain yield of the improved cultivar VC-5205A was highest but not significantly higher than the yield of Yezin-4. The yield of V-3726 was also high, but was significantly lower than that of the other two cultivars (Fig. 1).

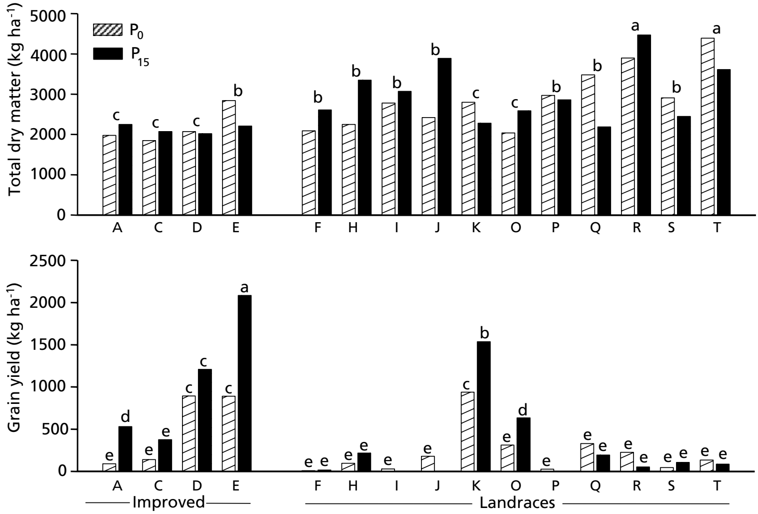
Figure 1: Effects of phosphorus (P) application at 0 and 15 kg P kg^{-1} as triple superphosphate on total dry matter and grain yield of 20 green gram genotypes grown in a field experiment at Yezin, Myanmar, 2001. *



* Cultivar identifiers are given in Table 1. Columns marked with different letters are significantly different at P<0.05.

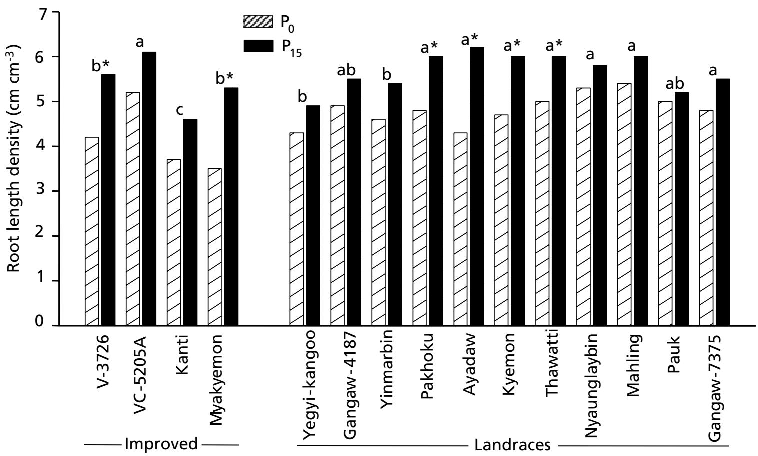
Among the landraces, Pakhoku and Ayadaw had the highest grain yields. No grain yields were harvested for Gangaw-4187 and Gangaw-7380 because of poor pod setting. In 2002 at Nyaung Oo, no grain yields were recorded for Gangaw-4187, Yinmarbin and Kyemon when P-fertilizer was applied, although they flowered (Fig. 2). Grain yields of the Myakyemon cultivar, in contrast, were twice as large with P than in the control treatment without P.

Figure 2: Effects of phosphorus (P) application at 0 and 15 kg P kg^{-1} as triple superphosphate on total dry matter and grain yield of 15 green gram genotypes grown in a field experiment at Nyaung Oo, Myanmar, 2002. *



* Cultivar identifiers are given in Table 1. Columns marked with different letters are significantly different at P<0.05.

Figure 3: Root length density of 15 green gram cultivars grown in a field experiment at Nyaung Oo, Myanmar, 2002 (0 and 15 kg P kg^{-1} as TSP). *



* Columns marked with different letters are significantly different at P<0.05

Figure 4: Effect of phosphorus (P) application at 0 and 15 kg P kg^{-1} as triple superphosphate on total dry matter and grain yield of six green gram genotypes grown at Yezin, Myanmar, 2003.

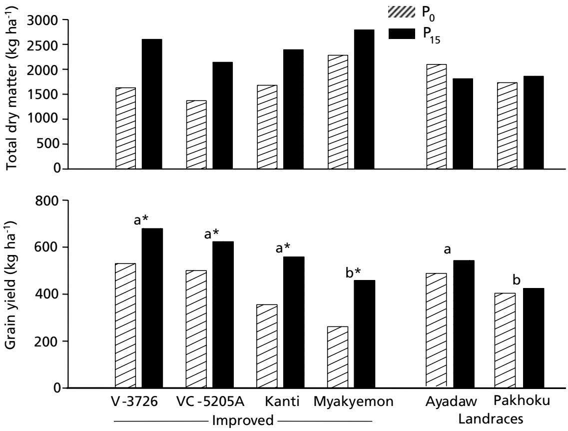
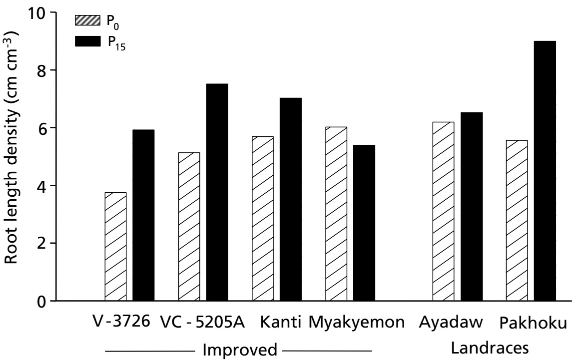


Figure 5: Effect of phosphorus (P) application at 0 and 15 kg P kg^{-1} as triple superphosphate (TSP) on root length density of six green gram genotypes grown at Yezin, Myanmar, 2003.



Root length density of all genotypes was significantly higher with P than in the unfertilised controls (Fig. 3). Significant differences in TDM and grain yield of green gram genotypes were noted again at Yezin in 2003 whereby TDM yields of the landraces Pakhoku and Ayadaw did not respond to P application even if RLD was significantly increased in both (Fig. 4 and 5).

At both sites P application reduced virus damage (Table 2 and 3). Compared to the unfertilised controls at Yezin, P application lead to an increased pest damage in improved cultivars and to its decrease in landraces. Although not significant, P application increased tissue N and P concentrations in all genotypes except for Kanti and Pakhoku, respectively (Table 4).

The analyses also showed large genotypic variation in the amino acid composition of the seeds in the ten green gram genotypes whereby Gangaw-4187, Magwe and Mahling had the highest lysine concentrations (Table 5).

Table 2: Effects of phosphorus (P) application at 0 and 15 kg P ha^{-1} on pest damage (%) and virus incidence (scored from 0 to 2) in different green gram cultivars at Nyaung Oo, Myanmar, 2002.

Cultivar †	*Pest damage (%)*		*Virus score* *	
	P_0	P_{15}	P_0	P_{15}
V-3726	12.1	11.5	1.5	1.3
VC-5205A	10.3	8.2	1.3	1.3
Kanti	7.4	10.9	1.5	1.0
Myakyemon	8.2	7.1	0.8	0.8
Yegyi-Kangoo	10.3	8.2	1.3	1.5
Gangaw4187	6.9	8.4	1.3	1.0
Yinmarbin	6.3	4.1	1.0	0.5
Pakhoku	10.2	9.3	1.3	1.3
Ayadaw	12.3	8.1	1.5	1.0
Kyemon	8.1	7.9	1.3	1.0
Thawatti	7.2	10.3	1.0	0.3
Nyaunglaybin	6.2	10.1	0.5	0.5
Mahling	7.3	9.9	1.8	1.8
Pauk	8.9	9.1	1.5	0.5
Ganggaw7375	8.2	7.1	1.3	1.5
Means	8.66	8.68	1.3	1.0
$\mathrm{LSD}_{0.05}$ for P ‡	-		0.22	
$\mathrm{LSD}_{0.05}$ for C ‡	-		0.54	

	Pr > F §	
P	0.520	0.031
Genotype	0.228	0.003
Genotype $\times$ P	0.741	0.707

* Scores were: 0 = no symptom, 1 = some mosaic, 2 = heavy mosaic virus

† Improved (V-3726, VC-5205A, Kanti, Myakyemon); Landraces (Yegyi-Kangoo, Gangaw4187, Yinmarbin, Pakhoku, Ayadaw, Kyemon, Thawatti, Nyaunglaybin, Mahling, Pauk, Ganggaw7375)

‡ Least significant difference at P<0.05

§ Probability of a treatment effect (significance level)

Table 3: Effects of phosphorus (P) application at 0 and 15 kg P ha^{-1} on pest damage (%) and virus incidence (scored from 0 to 2) in different green gram genotypes at Yezin, Myanmar, 2003.

Cultivar *	*Pest damage (%)*		*Virus score*	
	P_0	P_{15}	P_0	P_{15}
V-3726	6.5	6.7	1.5	0.8
VC-5205A	9.8	13.4	1.0	0.8
Kanti	6.9	10.3	1.5	0.5
Myakyemon	9.6	5.3	0.3	0.5
Pakhoku	11.5	8.8	0.5	0.5
Ayadaw	10.9	6.3	1.3	1.0
$LSD_{0.05}$ for P †	-		0.31	
$LSD_{0.05}$ for C †	-		0.54	
	Pr > F ‡			
P	0.635		0.037	
Genotype	0.520		0.026	
Genotype × P	0.485		0.207	

* Improved: V-3726, VC-5205A, Kanti and Myakyemon; Landraces: Pakhoku and Ayadaw
† Least significant difference
‡ Probability of a treatment effect (significance level)

Table 4: Effects of phosphorus (P) application at 0 and 15 kg P ha^{-1} on nitrogen and phosphorus concentration (mg kg^{-1}) in different green gram genotypes at Yezin, Myanmar, 2003.

Cultivar *	*Nitrogen*		*Phosphorus*	
	P_0	P_{15}	P_0	P_{15}
V-3726	30.3	31.6	3.14	3.18
VC-5205A	31.6	33.9	3.18	3.65
Kanti	33.8	31.8	3.35	3.38
Myakyemon	34.1	35.1	3.26	3.58
Pakhoku	32.4	32.3	3.09	3.02
Ayadaw	31.5	34.7	3.22	3.29
	Pr > F †			
P	0.352		0.093	
Genotype	0.492		0.092	
Genotype × P	0.739		0.421	

* Improved: V-3726, VC-5205A, Kanti and Myakyemon; Landraces: Pakhoku and Ayadaw
† Probability of a treatment effect (significance level)

Table 5: Amino acid concentrations (mmol $mmol^{-1}$ protein) in seeds of three improved cultivars and seven landraces of green gram from Myanmar, 2001.

Amino acid	*V-3726*	*VC-5205*	*Yezin-4*	*Ayadaw*	*Mahling*	*Gangaw-4187*	*Yegyi-Kangoo*	*Thawatti*	*Nyaung*	*Magwe*
Aspartate	204	185	202	242	253	259	236	245	193	256
Threonine	72	71	71	80	85	85	81	81	63	87
Serine	116	116	114	135	142	145	136	134	110	142
Glutamate	281	280	278	332	357	357	331	334	255	350
Glycine	123	124	131	144	165	162	148	152	122	164
Alanine	118	117	117	136	144	146	138	136	110	144
Cystine	5	5	5	5	6	6	4	5	4	6
Valine	112	109	115	131	135	138	131	132	104	137
Methionine	6	9	10	9	15	11	9	12	13	13
Isoleucine	79	77	78	93	93	96	92	93	73	96
Leucine	148	144	143	174	180	185	172	174	137	179
Tyrosine	34	33	34	40	44	42	40	42	32	45
Phenyalanine	84	83	81	100	103	106	98	102	79	104
Histidine	44	43	43	51	52	54	52	51	40	53
Lysine	117	115	118	134	144	146	137	139	110	146
Arginine	87	85	84	105	108	111	105	105	80	109
Proline	90	91	91	107	108	110	105	105	84	113
Protein (%)	36.0	36.1	35.9	35.7	35.4	35.5	35.7	35.9	36.0	35.6
Total (mmol)	1720	1687	1714	2018	2134	2158	2017	2042	1609	2144

3.2 Pot experiment

Across genotypes P application led to large increases in TDM and pod dry matter whereby TDM was highest for V-3726, although this difference was not significant. In contrast there were no genotypic differences for both parameters (Table 6). Similarly to shoot dry matter, there were no genotypic differences on RLD but compared to the unfertilised controls P application led to respective increases in RLD by 70%, 59%, 45% and 71% for cultivars V-3726, Yezin-4, Ayadaw and Mahling. Irrespective of P application and across genotypes grain N concentration was higher than shoot N whereby without P landraces tended to have lower shoot N than the improved genotypes V-3726 and Yezin-4 (Table 7). While P application led in all genotypes to significant increases in TDM and grain yield, genotype differences were only significant for grain yield.

Table 6: Effects of phosphorus (P) application at 0 and 15 kg P ha^{-1} on total dry matter (TDM), grain yield and root length density (RLD) of four green gram (*Vigna radiata* L.) cultivars grown in a pot experiment.

Cultivar *	*TDM* (*g plant*$^{-1}$)		*Grain yield* (*g plant*$^{-1}$)		*RLD* (*cm cm*$^{-3}$)	
	P_0	P_{15}	P_0	P_{15}	P_0	P_{15}
V-3726	3.7	6.2	1.2	1.5	5.7	7.0
Yezin-4	3.7	5.9	1.0	1.7	2.4	6.3
Ayadaw	3.8	5.5	0.9	1.1	3.9	4.8
Mahling	3.3	5.6	1.4	2.1	3.0	5.3
$LSD_{0.05}$ for P†	0.61		0.40		0.16	
			Pr > F ‡			
P	0.001		0.026		0.001	
Cultivar	0.715		0.106		0.332	
Cultivar × P	0.774		0.788		0.587	

* Improved: V-3726, Yezin-4; Landraces: Ayadaw and Mahling
† Least significant difference
‡ Probability of a treatment effect (significance level)

4 Discussion

The field experiments indicated a large genotypic variation in the TDM and grain yield increase following P application that was, however, not reproducible in the pot experiment. This could be due to the differences in the soils' chemical properties, but also to the lower light intensity and temperature in the German greenhouse conditions compared to the field conditions in Myanmar. Another reason may be genotypic differences in root growth that did not become apparent in the pot experiment with its restricted soil volume.

Table 7: Effects of phosphorus (P) application at an equivalent rate of 0 and 15 kg P ha^{-1} on shoot and seed nitrogen (N) concentration (mg g^{-1}) of four green gram genotypes grown in a pot experiment.

Cultivar *	*Shoot*		*Seed*	
	P_0	P_{15}	P_0	P_{15}
V-3726	1.59	1.38	3.03	3.38
Yezin-4	1.46	1.15	3.04	3.37
Ayadaw	1.27	1.38	3.04	2.98
Mahling	1.01	0.91	3.55	3.61
$LSD_{0.05}$ for C †	0.27		0.19	
	Pr > F ‡			
P	0.147		0.084	
Genotype	0.002		0.003	
Genotype × P	0.424		0.350	

* Improved: V-3726, Yezin-4; Landraces: Ayadaw and Mahling
† Least significant difference
‡ Probability of a treatment effect (significance level)

For groundnut in India (*Arachis hypogaea* L.) Chahal and Virmani (1973) reported significant genotypic differences in shoot growth after super phosphate application on a P poor soil. From an experiment in Sri Lanka Gunawardena *et al.* (1992) reported that green gram genotypes differed in growth response to P application leading to the conclusion that there may be scope for breeding efforts to enhance the growth response to P and thus the P use efficiency in this crop which suffers from P deficiency on many Asian soils with high P fixation and soil acidity. Another important reason for such future breeding efforts may be lacking availability of P fertilizers on national markets such as in Myanmar where annual NPK fertilizer consumption rate from 1983-85 to 1993-95 decreased by 4.7 % (FAO, 1996). For common bean (*Phaseolus vulgaris* L.) Araujo and Teixeira (2003) reported a high correlation between grain N and P concentrations and grain yield whereas the results of this study did not show any such correlation (r = 0.30 for N and r = 0.21 for P).

An effect which merits further study is the observed cultivar-specific reduction of virus infection with P application. Similar results were found earlier for *Phaseolus* beans by Costa (1976). In papaya (*Carica papaya* L.) the role of adequate plant nutrition for reduced infection and incidence of ring spot virus was demonstrated by Ray *et al.* (1999). Phosphorus application was also found to control crop diseases by enhancing mycorrhizal activities (Whipps, 2004). Differences in seed N due to P application were small in the experiments of our study. This is in contrast to findings of Shahi *et al.* (2002) in India who reported protein increases in green gram by 21% with the application of 26 kg P and 20 kg S ha^{-1}.

Although the overal protein quality was similar, the higher lysine and methionine concentrations (amount) in the Gangaw-4187, Magwe and Mahling, landraces was likely related to their lower seed yield. Genetic variation in lysine concentration is certainly important for future breeding programmes. However, it remains open to further investigation, how large genotype × environment interactions are for this trait.

5 Conclusions

This study indicated large genotypic differences for the effects of P application on shoot and root growth of green gram. In general grain yields were higher for improved cultivars than for landraces. The Myakyemon, Kanti and Pakhoku cultivars should be grown in the Nyaung Oo area while V-3726, VC-5205A and Ayadaw yielded better in the Yezin area. The particularly high lysine and methionine concentrations (amount) in the Myanmar landraces Gangaw-4187, Magwe and Mahling makes this germplasm interesting for regional quality breeding programs of green gram.

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References

Anishetty, N. M. and Moss, H.; *Vigna* genetic resources: Current status and future plans; in: *Mungbean: Proceedings of the Second International Symposium*; 13–18; AVRDC, Shanhua, Taiwan; 1988.

Araujo, A. P. and Teixeira, M. G.; Nitrogen and phosphorus harvest indices of common bean cultivars: Implications for yield quantity and quality; *Plant and Soil*; 257:425–433; 2003.

Chahal, R. S. and Virmani, S. M.; Preliminary study of the effect of time of application of Superphosphate on yield and nutrient uptake by groundnut; *Indian Journal of Agricultural Science*; 43:731–733; 1973.

Costa, A. S.; Whitefly-transmitted plant diseases; *Annual Review Phytopathology*; 14:429–449; 1976.

FAO; FAO Agrostat Data Base; Food and Agriculture Organization; Rome, Italy; 1996.

Gourley, C. J. P., Allan, D. L. and Russsele, M. P.; Plant nutrient efficiency: A comparison of definitions and suggested improvement; *Plant and Soil*; 158:29–37; 1994.

Gunawardena, S. F. B., Danso, S. K. A. and Zapata, F.; Phosphorus requirements and N_2 accumulation by three mungbean cultivars; *Plant and Soil*; 147:267–274; 1992.

James, C.; A manual of assessment keys for plant diseases; Canada Department of Agriculture Publication No. 1458, APS Press; 1971.

Jood, S. and Singh, M.; Amino acid composition and biological evaluation of the protein quality of high lysine barley genotypes; *Plant Food and Human Nutrition*; 56:145–155; 2001.

Lawes Agricultural Trust; *GENSTAT 5, Release 4.2; Reference Manual*; Harpenden, Herts, UK.; 2000.

Lawn, R. J. and Ahn, C. S.; Green gram (*Vigna radiata* L.); in: *Grain legumes crops*, edited by Summerfield, R. J. and Roberts, E. H.; 584–623; Collins, London; 1985.

Myanmar Times; Newspaper article on 7-12th January 2002 issue; Myanmar Times; 2002; URL
`http://www.myanmar.com/myanmartimes/Myanmartimes5-97/New/10.htm`.

Ray, P. K., Yadav, J. P. and Kumar, A.; Effect of transplanting dates and mineral nutrition on yield and susceptibility of papaya ring spot virus; *Horticulture Journal*; 12:15–26; 1999.

Shahi, D. K., Shama, A. and Singh, L.; Improvement in nutrition quality of green gram as influenced by fertilization and inoculation; *Indian Journal of Agricultural Science*; 72:210–212; 2002.

Tennant, D.; A test of a modified line intersect method of estimating root length; *Journal of Ecology*; 63:955–1001; 1975.

Thaung, P. E.; Status of pulses research and future strategies in Myanmar; in: *Proceedings of the second regional workshop on pulses*; 229–234; Bangladesh Agricultural Research Inst., Joydebpur (Bangladesh) and International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh (India), Joydebpur (Bangladesh). BARI; 1989.

Thomas, Robertson, M. J., Fukai, S. and Peoples, M. B.; The effect of timing and severity of water deficit on growth, development, yield accumulation and nitrogen fixation of mungbean; *Field Crops Research*; 86(1):67–80; 2004.

VDLUFA; Die Chemische Untersuchung von Futtermitteln; Methodenbuch Bd 3., Kap 1.11.1, VDLUFA, Darmstadt, Germany; 1988.

Whipps, J. M.; Prospects and limitations for mycorrhizas in biocontrol of root pathogens; *Canadian Journal of Botany*; 82:1198–1227; 2004.