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SELECTING MUNGBEAN GENOTYPES FOR FODDER PRODUCTION ON THE BASIS OF DEGREE OF INDETERMINACY AND BIOMASS

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Abstract

Rapid change in the environment due to global warming is not only linked with the scarcity of food but with the availability of green fodder also. Thirty mungbean genotypes were evaluated using randomized complete block design for fodder yield across years at two extreme environments of Pakistan; badly affecting by the flood. Broad-sense heritability and selection response were studied for degree of indeterminacy, petiole length, fresh and dry biomass. Significant differences at ($P \geq 0.01$) were spotted out among the genotypes at both locations for the parameters under study. All the genotypes responded differently for petiole length, fresh and dry biomass in selected years except degree of indeterminacy that did not affected by the weather change in a particular environment. Of the first order interactions (L×Y, G×L), variation was observed for degree of indeterminacy while; dry biomass was highly significant only for G×L and G×Y. However, G×L×Y was absolutely non-significant for parameters studied. The parameters studied for fodder purpose were greatly influenced by the two environments. Means for degree of indeterminacy, petiole length, fresh and dry biomass were 43.1 compared to 20.8, 13.8 compared to 15.5, 29.9 compared to 40.2 and 5.5 compared to 8.3 at Peshawar and Swat respectively. On the basis of degree of indeterminacy genotype 'NFM-8-1' was categorized as determinate and 'NFM-13-1' as highly indeterminate. The only genotype 'NFM-14-6' has maximum fresh and dry biomass, provided the better opportunity for selection as fodder for the extreme environments of Pakistan. The values for genetic variance were greater in magnitude than environmental variance at Peshawar than Swat for degree of indeterminacy. However, for the rest of the parameters the influence of environmental variance was higher at both locations. On the other hand genetic × year variances were almost negligible for the tested parameters. Heritability estimates for all the parameters and expected response to selection for most of the parameters were generally greater in magnitude at Peshawar than at Swat, except fresh biomass. Selection for degree of indeterminacy showed effectiveness at Peshawar than Swat. Broad- sense heritability and response to selection was enough high for fresh biomass at Swat suggested selection for the improvement of the said trait at Swat.

Introduction

Mungbean (*Vigna radiata* (L.) Wilczek) can considerably improve soil fertility through biological nitrogen fixation. Variation in plant height and classifying the mungbean genotypes as determinate or indeterminate at different stages of growth has already reported through diallel method of half cross development at pre and post flowering maturity. Inheritance mechanism for plant height at early and later pod maturity is supposed to be controlled by additive and dominant gene. To develop determinate mungbean genotypes, preference should be given to both types of narrow and broad sense heritability as greater the magnitude of heritability at later stages improving degree of indeterminacy and selection effectiveness (Khattak *et al*., 2002). The environmental conditions of Pakistan favor its wide cultivation twice in a single year. Climatic changes around the globe severely affected the availability of fodder for the livestock due to extensive pollution (Sharma & Dubey, 2005). Similarly, there are many other phytotoxic chemicals and elements that adversely affect the availability of generally cultivated fodder around the country (Moustakas *et al*., 1994; Aslam *et al*., 2010). Reductions in native plant biodiversity in natural and agro-ecosystems caused by natural disaster such as flood becoming an alarming threats for Pakistan. Fresh biomass serve as selection criteria for Boron tolerance also (Hasnain *et al*., 2011). We have not yet achieved a milestone of self-sufficiency in majorly consuming foods and our livestock are also dependent on dry straw of wheat and maize. Mungbean, like other fodders such as berseam and alfalfa is highly palatable legume attracted by the livestock and even more nutritious in nature. In tropical regions of Pakistan, mungbean is not only grown for seed but also as a short-term forage crop (Ullah *et al*., 2011a; Ullah *et al.*, 2011b). Most of the time breeder looking for stable and constant genotypes however, the fluctuated performance of mungbean genotypes crosswise environments confounds variety selection that can provide useful knowledge to the plant breeder for screening (Busey, 1983; Kang, 1998). Too many breeders have studied the yield and forage performance of mungbean using different selection indices. Ghafoor *et al*., (2000) suggested the use of harvest index and dry biomass as the good criteria for improvement in mungbean in the future. The scarcity of water is also changing the mind of breeders to think over the development of the evolvement of species that yield higher on little use of water. The two major problems to the tremendous yield of forage are unavailability of water or expensive ways of irrigation. Diversity in fresh and dry biomass productivity at drought and irrigated environments for several cropping seasons were studied. Mitchell *et al*., (1998) concluded that the greater biomass of sorghum than legumes was due to high water use efficiency, however among the legumes soybean and cowpea yielded greater than mungbean and lablab. Thus, the current study was undertaken to screen and evaluate the suitable mungbean genotypes for fodder purpose of sub-tropical and humid region of Pakistan using heritability and response to selection as basic variability tools.

Materials and Methods

The mungbean trials were conducted during the summer season of 2007 and 2008 at 2 diversified locations of Khyber Pakhtunkhwa Agricultural University, Peshawar and Agricultural Research Institute, Mingora, Swat of Khyber Pakhtunkhwa. Nuclear Institute for Food and Agriculture, Tarnab Peshawar is one of applied research institute, from where the seeds for the current study were obtained (Table 1). Prior conducting the trials soil and weather characteristics were studied thoroughly (Table 2 & 3). On the basis of soil analysis, NPK @ 65:115:55 kg ha^{-1} and micro nutrient deficiency of Zinc was necessitated with the application of 23% (27 kg ha^{-1}) of Zinc sulfate to the experiments at Peshawar. Similarly, NPK @ 55:105:50 kg ha^{-1} and 21% (27 kg ha^{-1}) Zinc sulfate were applied to the experiments at Swat. All nutrients were applied to the experimental units in the form of urea, di-ammonium phosphate and sulphate of potash as available sources of chemical fertilizers in the market. The experiment was laid out in a randomized complete block design on 6^{th} and 3^{rd} May 2007 and 2008, respectively at Peshawar however; at Swat the plantation was adjusted according to the temperature i.e., on 30^{th} and 16^{th} of May 2007 and 2008, respectively. Each experimental unit had three rows of four meter length with row to row distance of 30cm and plant to plant distance of 10cm. in-order to collect quality data on degree of indeterminacy (difference of plant height at maturity and flowering), petiole length (from main stem to leaf attachment point), fresh (at 90% pods maturity) and dry biomass (after 72 hours of sun drying) a single row was kept fallow within the experimental units.

Table 1. Pedigree details of mungbean genotypes evaluated in the study across years and locations.

Genotype	Pedigree	Genotype	Pedigree
NFM-5-63-4	VC 1482C × NM-92	NFM-12-12	VC 1482C × NM-92
NFM-5-63-10	VC 1482C × NM-92	NFM-12-15	VC 1482C × NM-92
NFM-5-63-13	VC 1482C × NM-92	NFM-13-1	6601 × NM-92
NFM-5-63-19	VC 1482C × NM-92	NFM-14-3	NM-92 × Pusa Baisaki
NFM-5-63-20	VC 1482C × NM-92	NFM-14-5	NM-92 × Pusa Baisaki
NFM-5-63-34	VC 1482C × NM-92	NFM-14-6	NM-92 × Pusa Baisaki
NFM-5-63-35	VC 1482C × NM-92	NFM-14-7	NM-92 × Pusa Baisaki
NFM-5-63-48	VC 1482C × NM-92	NFM-3-3	VC 3726 × NM-36
NFM-5-63-49	VC 1482C × NM-92	NFM-6-5	VC 1971 × NM-92
NFM-5-63-57	VC 1482C × NM-92	NFM-7-13	VC 1560D × NM-92
NFM-11-3	NM-92 × Black Mung	NFM-8-1	NM 93 × NM-92
NFM-12-3	VC 1482C × NM-92	NFM-8-22	NM 93 × NM-92
NFM-12-6	VC 1482C × NM-92	NM-92	VC 2768B × NM-36
NFM-12-7	VC 1482C × NM-92	NM-98	NM 20-21 × VC 1482E
NFM-12-8	VC 1482C × NM-92	Ramzan	VC1482C × NM-92

Table 2. Total rainfall, temperature, altitude/latitude and type of the soil of the two test sites.

	Peshawar		Swat	
	2007	2008	2007	2008
Total rainfall (mm)	195.8	304.0	475.6	542.3
Average minimum and maximum temperature (°C)	Min(°C)-Max(°C) 24.6-38.8	Min(°C)-Max(°C) 26.4-39.8	Min(°C)-Max(°C) 17.6-33.4	Min(°C)-Max(°C) 18.5-34.7
Latitude and longitude	Lat. 34° 01′ 10.38 N″ Long. 71° 28′ 01.70″ E Elevation. 364.6m		Lat. 34° 46′ 48.58 N″ Long. 72° 19′ 41.43″ E Elevation. 974 m	
Soil type	Silt loam/alkaline pH 8.1-8.2		Sandy loam/neutral pH 7.4-7.5	

Table 3. Soil characteristics of the two test sites for available macro and micro-nutrients.

Testing site	Macro Nutrients				Micro Nutrients		
	O.M (%)	N (%)	P (ppm)	K (ppm)	Iron (ppm)	Zinc (ppm)	Boron (ppm)
Agricultural University, Peshawar	0.76-0.80 (Average)	0.06-0.07 (Average)	6-7 (Weak)	93-118 (Average)	5.4-5.7 (Adequate)	0.7-0.8 (Deficient)	0.5-0.6 (Adequate)
Agricultural Research Institute, Swat	0.99-1.00 (Average)	13-15 (Optimum)	10-11 (Average)	120-132 (Optimum)	6.1-6.8 (Adequate)	0.8-0.9 (Deficient)	0.6-0.7 (Adequate)
Required level	≥ 2.7 %	≥2.2 %	≥16 ppm	≥ 153ppm	≥ 4.7 ppm	≥1.2 ppm	≥ 0.8ppm

Statistical analysis: To find out the level of significance, data obtained from mungbean genotypes across years and locations were analyzed through Annicchiarico (2002) model for randomized complete block design. For estimating broad-sense heritabilities (h^2_{BS}) for the selected parameters; genetic (V_g), genotype × year (V_{gy}) and error variances (V_e) at each location were figured out through Rowe and Brink (1993) technique. Using 20% selection intensity expected response (R_e) to selection for each trait (degree of indeterminacy, petiole length, fresh and dry biomass) at each location (Peshawar and Swat) was calculated using formula of Falconer and Mackay (1996).

Results and Discussion

Analysis of variance: To get a clear image of the degree of variability and level of significance, analysis of variance were done. Pooled analyses for degree of indeterminacy in term of plant elongation, petiole length, fresh and dry biomass depicted highly significant differences (P≤0.01) among mungbean genotypes across years and across locations (Table 4). Of the first order interactions, L×Y and G×L were highly significant (P≤0.01) for degree of indeterminacy and dry biomass. However, for the fresh value of biomass the variation was counted for interaction due to G×L. In contrast G×Y interaction effect was non-significant for the tested parameters except dry biomass. The 2nd order interaction plays major role in selecting suitable genotypes for diversified environments. In the current study G×L×Y interaction was absolutely non-significant for all the related parameters. The relative magnitude of genotype (G) counted was 16.09, 24.62, 15.66 and 12.28% respectively for degree of indeterminacy, petiole length, fresh and dry biomass. This showed that for these parameters the major genetic contribution was for petiole length. Environment (E) is the non-controlling agent in any experimental design. Location (L), year (Y), L×Y and error due to reps within each location collectively contributed towards E. For degree of indeterminacy, petiole length, fresh and dry biomass E explained 42.50, 19.12, 58.59 and 51.81% of the variation. These findings suggested that the environment had greater influence on the expression of these attributes. To breed for a selected environment the role of genotype-by-environment (GE) interaction can't be avoided which was the sum of percent variation due to G×L, G×Y and G×L×Y in this particular study. Though the magnitude of GE was comparatively lesser than G and E and even non-significant in most cases. Variation due to GE was 14.80, 13.72, 17.03 and 20.41% for degree of indeterminacy, petiole length, fresh and dry biomass. Greater variation due to environment necessitated the need to breed for specific adaptation (Ullah *et al.,* 2011b). Although soil factor was fixed for the two years experimentation, however, dealing with mungbean advanced lines Ullah *et al*., (2011c) explained the mechanism of environmental influence on the yield fluctuation of mungbean. The quickest vegetative growth in early stages (prior flower initiation) in mungbean genotypes encouraged high dry matter accumulation broader leaf area index and also increased number of plants per unit area and were highly under the control of environmental effects (Tickoo *et al*., 1996). Ahmad *et al*., (2008) suggested that the copper and lead resistance genotypes such as Mung-1 could increase the photosynthetic activity that ultimately a best source to stand with elongated petiole and hence enhance the photosynthesis. Ullah *et al*., (2011c) concluded that most of the mungbean genotypes had less harvest index and the ratio of fresh and dry biomass were more that, favored the majority of mungbean genotypes good for fodder usage.

Table 4. Mean squares for degree of indeterminacy, petiole length, fresh and dry biomass of 30 mungbean genotypes evaluated for two years at two locations of Khyber Pakhtunkhwa during 2007 and 2008.

Sources of variation	Degrees of freedom	Degree of indeterminacy	Petiole length	Fresh biomass	Dry biomass
Location (L)	1	44253.5** (35.91)	251.3** (7.34)	9530.5** (29.26)	696.1** (44.78)
Year (Y)	1	0.8^{NS} (0.00)	172.5** (5.03)	2076.0** (6.36)	70.4** (4.60)
L×Y	1	178.9** (0.15)	3.0^{NS} (0.09)	2.7^{NS} (0.01)	1.7^{NS} (0.06)
Rep (L×Y)	8	992.5 (6.44)	28.5 (6.66)	120.7 (2.96)	3.7 (2.37)
Environment (E)	---	------- **(42.50)**	------- **(19.12)**	------- **(38.59)**	------- **(51.81)**
Genotype (G)	29	683.6** **(16.09)**	29.1** **(24.62)**	175.8** **(15.66)**	5.8** **(12.28)**
G×L	29	603.6** (14.20)	5.4^{NS} (4.58)	112.9** (10.03)	6.0** (12.82)
G×Y	29	12.1^{NS} (0.28)	7.5^{NS} (6.34)	56.7^{NS} (5.04)	2.1** (5.31)
G×L×Y	29	13.0^{NS} (0.31)	3.3^{NS} (2.81)	21.9^{NS} (1.96)	0.9^{NS} (2.28)
G×E	---	------- **(14.80)**	------- **(13.72)**	------- **(17.03)**	------- **(20.41)**
Error	232	141.4 (26.62)	6.3 (42.53)	40.3 (28.71)	0.8 (15.49)

Values in the parenthesis are the percent of total sum of squares, ** = Significant at 1% probability level ^{NS} = Non-significant

Means, broad-sense heritability and selection response

Degree of indeterminacy: Likewise many other cultivated species, mungbean are also having either determinate or indeterminate growth pattern. Information regarding growth pattern (degree of indeterminacy) providing tools to plant breeder and restrict to specific breeding method while developing for fodder purpose. According to Anon., (1976) the variation caused due to the vegetative growth prior and after flowering in legumes referred to as degree of indeterminacy of plant height. Degree of indeterminacy among thirty mungbean genotypes evaluated at two locations of Khyber Pakhtunkhwa ranged from 15.6 to 67.5% at Peshawar and 9.4 to 38.8% at Swat (Table 5). It was noted that almost 97% of the mungbean genotypes at Peshawar showed growth pattern of indeterminacy as the post-flowering growth enhanced plant height. Genotypes with maximum degree of indeterminacy were not consistent at two locations showed environmental variation. Of the thirty mungbean genotypes evaluated at both locations for two consecutive years, NFM-5-63-4 (67.5%) and NFM-14-7 (38.8%) were classified indeterminate at Peshawar and Swat, respectively. Averaged over 30 mungbean genotypes, the degree of indeterminacy at Peshawar was greater in magnitude than that of Swat, showed the variation in weather factors such as temperature, soil, humidity and air flow. Averaged across years and locations, mungbean genotypes NFM-11-3, NFM-14-5 and NFM-12-8 had 44.0, 43.5 and 42.9% stem elongation, whereas NFM-8-1 (12.5%) was categorized as determinate. Breeding for determinate type of genotype, emphasis should be given to selections at advanced stages. Little increase in plant height after flower initiation is good to get maximum seed yield by suppressing the competition among the legumes (Shanmugasundaram *et al*., 1977). Mungbean genotypes that discontinue vegetative growth in term of stem elongation after blooming were termed as determinate and vice versa (Lampang *et al*., 1988).

Table 5. Means for plant height and degree of indeterminacy of plant height of 30 mungbean genotypes evaluated at two locations of Khyber Pakhtunkhwa during 2007-2008.

Genotypes	Degree of indeterminacy (%)			Petiole length (cm)		
	Peshawar	Swat	Mean	Peshawar	Swat	Mean
NFM-5-63-4	67.5	9.4	38.5	16.7	13.8	15.3
NFM-5-63-10	27.3	21.2	24.3	11.3	12.6	12.0
NFM-5-63-13	52.5	14.9	33.7	13.8	16.8	15.3
NFM-5-63-19	34.6	15.8	25.2	13.3	15.3	14.3
NFM-5-63-20	47.2	12.7	30.0	13.8	15.8	14.8
NFM-5-63-34	49.8	28.3	39.1	13.5	16.5	15.0
NFM-5-63-35	52.7	12.4	32.6	11.2	13.4	12.3
NFM-5-63-48	55.4	12.1	33.8	12.2	14.5	13.4
NFM-5-63-49	35.5	30.5	33.0	11.3	15.3	13.3
NFM-5-63-57	36.8	13.6	25.2	13.2	15.6	14.4
NFM-11-3	56.2	31.7	44.0	16.2	16.9	16.6
NFM-12-3	53.9	17.9	35.9	15.2	16.7	16.0
NFM-12-6	46.8	22.6	34.7	15.6	16.3	16.0
NFM-12-7	53.3	31.7	42.5	15.4	17.9	16.7
NFM-12-8	52.5	33.2	42.9	17.9	18.4	18.2
NFM-12-12	53.9	19.4	36.7	15.6	16.0	15.8
NFM-12-15	34.3	15.4	24.9	15.1	18.0	16.6
NFM-13-1	42.0	19.9	31.0	12.9	14.5	13.7
NFM-14-3	46.6	9.4	28.0	14.2	14.7	14.5
NFM-14-5	49.8	37.2	43.5	15.7	18.1	16.9
NFM-14-6	34.0	13.1	23.6	13.6	14.2	13.9
NFM-14-7	43.9	38.8	41.4	14.6	17.6	16.1
NFM-3-3	35.7	25.7	30.7	14.0	16.2	15.1
NFM-6-5	37.9	14.5	26.2	13.1	13.6	13.4
NFM-7-13	22.4	20.5	21.5	11.6	14.1	12.9
NFM-8-1	15.6	9.4	12.5	11.9	15.6	13.8
NFM-8-22	30.8	27.7	29.3	12.7	13.5	13.1
NM-92	23.8	24.5	24.2	11.5	12.8	12.2
NM-98	45.1	23.0	34.1	14.2	16.0	15.1
Ramzan	53.8	18.0	35.9	13.7	14.2	14.0
Mean	43.1	20.8	----	13.8	15.5	----
LSD $_{(0.05)}$	3.8	4.5	2.9	2.8	2.7	2.3
CV (%)	21.7	67.2	37.3	14.0	19.2	17.1

Genetic variance for degree of indeterminacy was around twice at Peshawar (140.82) than Swat (69.51). Though genetic variance was 1.61 times greater at Peshawar than error variance, however, the same was almost three times slighter than the respective value of error variance at Swat. Magnitude of broad-sense heritability calculated for degree of indeterminacy at Peshawar (0.83) was greater than that of Swat (0.52). This showed that heritability values for this trait at Peshawar are greatly under the control of genetic action compared to that calculated for the same trait at Swat (Table 7). Khattak *et al*., (2002) suggested that breeding for determinate type of mungbean genotypes, the preference should be given to high broad-sense heritability, as the improvement will be more effective and successful. Many researchers calculated different values of broad-sense heritability with variation however, Poehlman (1991) and Khattak *et al*., (1997) reported highest magnitude of heritability for degree of indeterminacy. Response to selection was 15.12 vs. 8.39% at Peshawar and Swat with 20% selection intensity. On the basis of selection response best results were expected at Peshawar than Swat for degree of indeterminacy. These findings are in agreement with Ullah *et al*., (2011a) who had also reported high broad sense heritability for yield and morpho-physiological parameters for the same set of genotypes.

Fresh biomass: Less proper management and non-judicial use of fertilizer in Pakistan has almost deteriorated the fertility and productivity of major crops. Mungbean crop is known for maximum biomass to improve soil structure by proper incorporation to the soil for the coming season. To improve soil physical structure, enhance nutrient exchange capacity for crop growth and to sustain fertile soil from erosion, mungbean fresh biomass must be meshed in the prevailing cropping system (Becker *et al*., 1995). Fresh biomass at Peshawar ranged from 26.0 to 38.3 t ha^{-1} and 29.2 to 52.3 t ha^{-1} at Swat for thirty mungbean genotypes (Table 6). Performance of mungbean genotypes was almost superior at Swat and 29 of the thirty genotypes produced maximum fresh biomass than Peshawar. Averaged over 30 genotypes across years mean fresh weight was 29.9 t ha^{-1} at Peshawar and 40.2 t ha^{-1} at Swat. Averaged over two locations mean maximum fresh biomass (42.8 t ha^{-1}) was recorded each for NFM-5-63-35 and NFM-14-6. In contrast, over two locations and years, NFM-3-3 and NFM-5-63-20 had 28.1 and 29.6 t ha^{-1} least fresh biomass respectively. For NM-98, the study showed a positive association of seed yield (not given) with fresh biomass. Similarly, for NFM-14-6 fresh biomass was associated with the maximum number of pods plant^{-1} (not given) but had the shortest plant height (Ullah *et al*., 2011a-c). NFM-12-3 was the 4th high yielding genotype for fresh biomass had maximum number of pods and expanded leaf area. As stated genotype NFM-3-3 and NFM-5-63-20 recorded for least fresh biomass ultimately had lesser number of pods plant^{-1} and seed yield ha^{-1} (not given), respectively. In the case of genotype NFM-8-1, it was observed that the minimum fresh biomass was due to the short stature and lowest number of functional leaves among the genotypes tested (Ullah *et al*., 2011b).

Table 6. Means for fresh and dry biomass of 30 mungbean genotypes evaluated at two locations of Khyber Pakhtunkhwa during 2007-2008.

Genotypes	Fresh biomass (t ha^{-1})			Dry biomass (t ha^{-1})		
	Peshawar	Swat	Mean	Peshawar	Swat	Mean
NFM-5-63-4	28.1	46.1	37.1	4.4	8.8	6.6
NFM-5-63-10	36.7	42.0	39.4	6.9	8.8	7.9
NFM-5-63-13	33.8	39.4	36.6	5.6	7.0	6.3
NFM-5-63-19	29.4	30.9	30.2	6.6	9.2	7.9
NFM-5-63-20	26.8	32.3	29.6	5.1	6.3	5.7
NFM-5-63-34	27.4	36.8	32.1	6.1	7.3	6.7
NFM-5-63-35	35.4	50.2	42.8	5.8	6.9	6.4
NFM-5-63-48	29.6	40.0	34.8	5.9	9.4	7.7
NFM-5-63-49	29.0	42.4	35.7	5.8	8.8	7.3
NFM-5-63-57	28.2	40.6	34.4	5.3	7.8	6.6
NFM-11-3	34.4	31.3	32.9	7.9	8.1	8.0
NFM-12-3	32.2	46.8	39.5	4.7	9.3	7.0
NFM-12-6	26.4	39.1	32.8	6.9	9.3	8.1
NFM-12-7	26.5	35.8	31.2	4.8	7.3	6.1
NFM-12-8	28.0	37.5	32.8	4.7	8.4	6.6
NFM-12-12	30.9	42.6	36.8	4.8	9.1	7.0
NFM-12-15	31.5	32.2	31.9	5.1	6.9	6.0
NFM-13-1	26.6	42.2	34.4	4.3	9.2	6.8
NFM-14-3	32.6	34.6	33.6	5.2	7.5	6.4
NFM-14-5	28.6	39.7	34.2	4.2	8.9	6.6
NFM-14-6	35.5	50.1	42.8	6.8	9.5	8.2
NFM-14-7	26.0	52.3	39.2	4.3	9.1	6.7
NFM-3-3	27.0	29.2	28.1	5.7	6.3	6.0
NFM-6-5	26.2	37.9	32.1	4.6	9.5	7.1
NFM-7-13	30.0	43.6	36.8	5.7	10.0	7.9
NFM-8-1	26.0	35.4	30.7	4.9	9.1	7.0
NFM-8-22	28.7	41.3	35.0	5.3	7.8	6.6
NM-92	31.6	46.0	38.8	6.6	8.3	7.5
NM-98	38.3	44.2	41.3	7.1	8.0	7.6
Ramzan	26.9	44.6	35.8	4.9	7.7	6.3
Mean	29.9	40.2	----	5.5	8.3	----
LSD $_{(0,05)}$	7.9	6.9	6.3	1.4	1.5	1.2
CV (%)	18.5	17.6	18.1	16.4	10.1	12.6

Petiole length: Greater variation across locations was observed for petioles on mean basis. A total of 29 mungbean genotypes had longest petioles at Swat due to humidity than that of Peshawar for the said set of genotypes (Table 5). At Peshawar the length of petiole recorded in between 11.2 and 17.9 cm while, it was 12.6 to 18.4 cm at Swat. Genotype NFM-12-8 at both locations excelled longest petiole meanwhile; shortest petiole was recorded for genotypes NFM-5-63-35 (11.2cm) and NFM-5-63-10 (12.6cm) across locations. Mean petiole length averaged over 30 genotypes at Peshawar was 13.8cm while it was 15.5cm at Swat. Averaged over two years and locations among the thirty genotypes NFM-12-8 (18.2cm) had longest petiole followed by genotype NFM-4-5 (16.9cm). Similarly, NFM-5-63-10 (12.0cm) and NM-92 (12.2cm) were categorized as shortest petiole bearing genotypes across years and locations. Longest petiole allows the genotypes to get expose the leaf blade to sunshine for maximum sunlight interception.

Genetic variance (2.12cm) was comparatively greater in magnitude at Peshawar than that at Swat (1.83cm) for petiole length. At both locations the variance controlled genetically was less than its respective error variance at both locations (Table 7). This showed the greater influence of the environment at both locations on the expression of the genotypes for petiole length. Though the genetic control was less however, the broad-sense heritability for petiole length was relatively high in magnitude at Peshawar (0.54) than (0.38) at Swat. Selection would be effective for longest petiole at Peshawar (1.49cm) than at Swat (1.17cm) at 20% selection intensity that is directly proportional to forage yield. Consequent upon these findings Makeen *et al*., (2007) and Sriphadet *et al*., (2005) reported moderate to slight high heritability for petiole length in mungbean. In contrast Khattak *et al*., (1997) and Siddique *et al*., (2006) observed high heritability and suggested improvement through genetic manipulation.

Genetic variance for fresh biomass was almost 6 times greater in magnitude at Peshawar (4.8 t ha^{-1}) than at Swat (30.2 t ha^{-1}). However, genetic variance was about 0.1 times greater than the respective genetic-by-year variance at Peshawar (Table 7). As the environmental effect was slightly high at both locations for fresh biomass enhanced the error variance than the respective genetic variance. Due to low genetic variance at Peshawar the broad-sense heritability (0.25) was comparatively less than that of Swat (0.64), indicated moderate to perfect genetic control for this important parameter at Swat rather at Peshawar. High heritability at Swat also prompted for high selection response (6.17 t ha^{-1}) at 20% selection intensity.

Table 7. Genetic variance (V_g), genetic- by-year variance (V_{gy}), environmental variance (V_e), broad-sense heritability (h^2_{BS}) and selection response (R_e) for agronomic traits of 30 mungbean genotypes evaluated at two locations of Khyber Pakhtunkhwa during 2007 and 2008.

Agronomic traits	Peshawar					Swat				
	V_g	V_{gy}	V_e	$h^2_{(BS)}$	R_e	V_g	V_{gy}	V_e	$h^2_{(BS)}$	R_e
Deg. of indeterminacy (%)	140.82	-25.69§	87.54	0.83	15.12	69.51	-60.19§	195.21	0.52	8.39
Petiole length (cm)	2.12	0.58	3.74	0.54	1.49	1.83	-1.16	8.82	0.38	1.17
Fresh biomass (t ha^{-1})	4.8	4.7	30.8	0.25	1.53	30.2	-5.4	49.9	0.64	6.17
Dry biomass (t ha^{-1})	0.69	0.20	0.82	0.59	0.89	0.79	0.28	0.69	0.60	0.97

§ Values with negative sign were considered zero in estimation of $h^2_{(BS)}$

Dry biomass: Seed yield of mungbean is directly proportional to the accumulation of biomass. Study revealed that plant growth and seed yield formation in mungbean genotypes are subjected to abiotic stresses in different environments (Cruz de Carvalho *et al.,* 1998). Dry biomass for 2 consecutive years ranged from 4.2 to 7.9 t ha^{-1} vs. 6.3 to 10.0 t ha^{-1} at Peshawar and Swat, respectively. The favorable environment for the expression of this trait was Swat for all the tested genotypes. An increase from 0.2 to 4.9 t ha^{-1} was recorded at Swat for the set of mungbean genotypes. Averaged over 30 genotypes for two years at Peshawar; dry biomass was 5.5 while at Swat it was 8.3 t ha^{-1} (Table 6). Averaged over locations, the maximum mean value for dry biomass was noted for mungbean genotypes NFM-14-6 (8.2 t ha^{-1}) and NFM-12-6 (8.1 t ha^{-1}). Maximum dry biomass of NFM-14-6 might be due their highest fresh biomass however, for NFM-12-6 this would be due to maximum plant height. The lowest dry biomass was recorded for NFM-5-63-20 (5.7 t ha^{-1}) followed by NFM-12-15 and NFM-3-3 each had 6.0 t ha^{-1} of dry biomass. Least dry biomass of these genotypes was due to their minimum fresh biomass and exposure to sunlight for a period of 72 hours. Similarly, genotype NFM-5-63-20 had broader leaf area but was low yielding and thus had least dry biomass (Ullah *et al*., 2011a). The maximum dry biomass of the tested genotypes was comparatively high than that reported would be due to the genotypes used or their exposure period to sunlight that may have not provided enough time for evaporation. Hamid *et al*., (2004) reported a dry matter ranged from 2.24 to 2.86 t ha^{-1} for mungbean genotypes in Bangladesh. These results were in contrast to the mean values reported for dry biomass by Khattak *et al*., (2003) with 120 hours of sun drying in mungbean.

Genetic and genetic-by-year variance for dry biomass was 0.69 and 0.20 at Peshawar compared to 0.79 and 0.28 at Swat (Table 7). Genetic variance was 3.5 and 2.8 times greater than corresponding values of genetic-by-year variance at Peshawar and Swat, respectively. As the broad-sense heritability was calculated from genetic, genetic-by-year and error variance thus, heritability for dry biomass was almost same at both locations (0.59 and 0.60) indicated moderate genetic control. Similarly, response to selection at 20% selection intensity for dry biomass was 0.89 vs. 0.97t ha^{-1} at Peshawar and at Swat, respectively. Ikramullah *et al*., (2011) linked the differential heritability and selection responses with simultaneous evaluation and selection of genotypes across locations.

Conclusions

To select determinate or indeterminate mungbean genotype best time is delayed selection. Long petiole allowed the leaves exposure to sunlight that might have enhanced the photosynthesis that increased the accumulation of biomass. Similarly, the low evapotranspiration and low relative humidity are the positive factors for fresh biomass. Genotypes 'NFM-5-63-35' and 'NFM-14-6' had maximum fresh and dry biomass ease the selection as fodder cultivar. Genetic variance for degree of indeterminacy, petiole length, fresh and dry biomass was greater in magnitude than their respective genetic-by-year variance. Estimates of heritability were higher only for dry biomass at both locations. However, fresh biomass had high heritability at Swat only, suggested that preference should be given to Swat location if breeding objective is to select for fodder purpose only. High selection response at 20% intensity was recorded for degree of indeterminacy at both locations however; fresh biomass had more response to selection at Swat only. Genotype 'NFM-14-6' had the potential to be released for wide cultivation in humid and subtropical region of Pakistan, however, on the basis of degree of indeterminacy and petiole length the selection should be restricted to specific adaptation.

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References

Ahmad, M.S.A., M. Hussain, S. Ijaz and A.K. Alvi. 2008. Photosynthetic performance of two mung bean (*Vigna radiata* (L.) Wilczek) cultivars under lead and copper stress. *Int. J. Agri. Biol*., 10: 167-72.

Annicchiarico, P. 2002. Genotype × environment interaction: Challenges and opportunities for plant breeding and cultivar recommendations. *FAO Plant Production and Protection Paper* 174, United Nations, Rome.

Anonymous. 1976. *Mungbean report for 1975*. Asian Vegetable Research Development Center (AVRDC), Shanhua, Tainan, Taiwan.

Aslam, M., N. Hussain, M. Zubair, S.B. Hussain and M. S. Baloch. 2010. Integration of organic & inorganic sources of phosphorus for increased productivity of mungbean (*Vigna radiata*). *Pak. J. Agri. Sci*., 47:111-114.

Becker, M., J.K. Ladha and M. Ali. 1995. Green manure technology: Potential usage, limitation: a case study for low land rice. *Plant Soil*, 174: 181-194.

Busey, P. 1983. Management of crop breeding. In: *Crop breeding*. (Ed.): D.R. Wood. ASA, CSSA, Madison, WI. pp. 31-54.

Cruz de Carvalho, M.H., D. Laffray and P. Louguet. 1998. Comparison of the physiological responses of *Phaseolus vulgaris* and *Vigna unguiculata* cultivars when subjected to drought conditions. *Environ. Exp. Bot*., 40: 197-207.

Falconer, D.S and T.F.C. Mackay. 1996. *Introduction to quantitative genetics*. 4th ed. Longman Scientific and Technical, England.

Ghafoor, A., M.A. Zahid, Z. Ahmad, M. Afzal and M. Zubair. 2000. Selecting superior mungbean lines on the basis of genetic diversity and harvest index. *Pak. J. Biol. Sciences*, 3(8): 1270-1273.

Hamid, A., H.M. Haque, N.A. Mondal, Z.A. Sarker and M.S. Aktar. 2004. The effect of incorporation of mungbean residue on the productivity of rice. In: *Proceedings of the Final Workshop and Planning Meeting*. (Ed.): S. Shanmugasundaram. 2006. May 27-31, 2004, Punjab Agricultural university, Ludhiana, Punjab, India. pp. 29-34.

Hasnain, A., S. Mahmood, S. Akhtar, S.A. Malik and N. Bashir. 2011. Tolerance and toxicity levels of boron in mung bean (*Vigna radiata* (L.) Wilczek) cultivars at early growth stages. *Pak. J. Bot*., 43(2): 1119-1125.

Ikramullah, I. H. Khalil1, H. U. Rahman, F. Mohammad, H. Ullah and S.K. Khalil. 2011. Magnitude of heritability and selection response for yield traits in wheat under two different environments. *Pak. J. Bot*., 43(5): 2359-2363.

Kang, M.S. 1998. Using genotype-by-environment interaction for crop cultivar development. *Adv. Agron*., 62: 199-252.

Khattak, G.S.S., M. Ashraf, M.A. Haq, T. McNeilly and E.S. Rha. 2002. Genetic basis of plant height and its degree of indetermination in mungbean (*Vigna radiata* (L.) Wilczek. *Hereditas*, 137: 52-56.

Khattak, G.S.S., M. Ashraf, T. Elahi and G. Abbas. 2003. Selection for large seed size at the seedling stage in Mungbean (*Vigna radiata* (L.) Wilczek). *Breed. Sci*., 53: 141-143.

Khattak, G.S.S., Razi-ud-Din, F. Hanan and R. Ahmad. 1997. Genetic analysis of some quantitative character in mungbean. *Sarhad J. Agric*., 13: 371-376.

Lampang, A.N., S. Pichitporn, S.S. Sin and N. Vanakijinongkol. 1988. Mungbean growth pattern in relation to yield. In: *Mungbean*. (Ed.): S. Shanmugasundaram. *Proc. 2nd Intl. Symp*. AVRDC, Shanhua, Tainan, Taiwan, pp. 164-168.

Makeen, K., G. Abrahim, A. Jan and A.K. Singh. 2007. Genetic variability and correlations studies on yield and its components in mungbean (*Vigna radiata* (L.) Wilczek). *J. Agron*., 6: 216-218.

Mitchell, J.H., S. Fukai, B. Konabe, C. Makonta and J. Challe. 1998. Evaluation of legume and cereal fodder species for variation in water use. "Agronomy, growing a greener future?". Edited by DL Michalk and JE Pratley. *Proceedings of the 9th Australian Agronomy Conference*, 20-23 July 1998, Charles Sturt University, Wagga Wagga, NSW.

Moustakas, M., T. Lanaras, L. Symeonidis and S. Karataglis. 1994. Growth and some photosynthetic characteristics of field grown *Avena sativa* under copper and lead stress. *Photosynthetica*, 30: 389-96.

Poehlman, J.M. 1991. The mungbean. University of Missouri, Columbia, USA.

Rowe, D.E and G.E. Brink. 1993. Heritabilities and genetic correlations of white clover clones grown in three environments. *Crop Sci*., 33: 1149-1152.

Shanmugasundaram, S., C.S. Tsou and S.T.T. Samson. 1977. Selection of plant types in breeding tropical soybean. *Bull. Inst. Trop. Agr.* Kyushu Univ., 2: 25-39.

Sharma, P. and R.S. Dubey. 2005. Lead toxicity in Plants. *Brazil J. Plant Physiol*., 17: 35-52.

Siddique, M., M.F.A. Malik and S.I. Awan. 2006. Genetic divergence, association and performance evaluation of different genotypes of mungbean (*Vigna radiata*). *Intl. J. Agric. Bio*., 8: 793-795.

Sriphadet, S., C.J. Lambrides and P. Srinives. 2008. Inheritance of agronomic traits and their interrelationship in mungbean (*Vigna radiata* (L.) Wilczek). *J. Crop Sci. Biotech*., 10: 249-256.

Tickoo, J.L., M.R. Gajraj and C. Manji. 1996. Plant type in mungbean (*Vigna radiata* (L.) Wilczek). In: *Proc. Recent Adv. in Mungbean Res*. (Eds.): A.N. Asthana and D.H. Kim. *Indian Soc. of Pulses Res*., Kanpur, India, pp. 197-213.

Ullah H, I.H. Khalil, H.U. Rahman, F. Muhammad, I.A. Khalil and S.K. Khalil. 2011a. Environmental influence on heritability and selection response of morpho-physiological traits in mungbean. *Pak. J. Bot*., 43(1): 301-310.

Ullah H, I.H. Khalil, I.A. Khalil and G.S.S. Khattak. 2011b. Performance of mungbean genotypes evaluated in multi-environmental trials using the GGE biplot method. *Atlas J. Biotechnol.,* 1: 1-8.

Ullah H, I.H. Khalil, Iltafullah, H.U. Rahman and I. Amin. 2011c. Genotype × environment interaction, heritability and selection response for yield and yield contributing traits in mungbean. *Afr. J. Biotechnol*., 10: 475-483.

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