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Research Article

Mung Bean (*Vigna radiata* L.) genotypes assessment for drought tolerance in Uzbekistan

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Abstract

Globally, increasing water and energy demand is expected to reach 6.9 trillion cubic meters by 2030, exceeding 40% of the available water supplies. Climate change and rising temperatures caused water deficit due to lesser and irregular rainfalls, leading to lower production of crops. The research to assess drought tolerance of Mung Bean (*Vigna radiata* L.) genotypes in Uzbekistan revealed the cultivar, Ishonch as the most promising for drought environments. The research, in a randomized complete block design (RCBD) in three replications with a factorial arrangement and two irrigation regimes (non-stress and water stress at the seedling stage), was conducted at the experimental field of the Institute of Genetics and Plant Experimental Biology, District Kibray, Tashkent Region, Uzbekistan. Ten Mungbean cultivars, i.e Durdona, Barqaror, Marjon, Andijon-1, Zilola, Ishonch, Baraka, L-59, L-88 and L-92 with diverse agronomic characteristics, were selected for their potential yield during 2022 and 2023 cropping seasons under two different environments (optimal and water deficit condition). In the Uzbekistan region, yield index, yield stability index, stress intensity, stress susceptibility percentage index, stress susceptibility index, stress tolerance index, drought intensity index, tolerance index, geometric mean productivity, relative drought index, mean relative performance, harmonic mean, mean productivity and sensitivity drought indices and their cluster analysis results were determined. The mungbean Durdona and T-59 genotypes were found to be prone to water deficit conditions. The Ishonch, Barqaror ва L-92 genotypes were found to be a positive donor in the selection for drought.

Keywords: *Vigna radiata* L., Mung beans, cultivar, line, morphology, yield

Introduction

Irrigation water resource is the most important and widely operative limiting factor for crop production. Responses of plants to water deficit conditions have been employed to make a physiological evaluation of drought resistance. Mung bean (*Vigna radiata* L.) belonging to the family *Fabaceae* is an important pulse crop grown widely in arid and semi-arid regions and it thrives well under drought-prone conditions. Mung bean not only augments the soil fertility status but also breaks the soil exhaustion caused by cereal-cereal crop rotations (Singh *et al.,* 2014). Mung bean can be grown under low moisture and fertility conditions; is one of the important grain legumes in the rain-fed farming systems in dry and intermediate zones of Sri Lanka. At present Mung bean is one of the most popular short-duration grain legumes grown during dry regions and dry seasons as rice intercrop in Sri Lanka. Mung bean in a rice rotation has increased the yield of paddy and the income of farmers in Punjab (Weinberger, 2003).

Water stress is one of the most significant agricultural problems worldwide, due to its effects on the productivity of crops (He *et al.,* 2018, Shavkiev *et al*., 2022). Climate change is expected to increase water stress by about 20 % in the current century (Makamov *et al*., 2023). The threat is due to water scarcity and to stress caused by extreme temperatures and salinity (Shavkiev *et al*., 2021). The world population is expected to grow by 50% in the coming years, thus increasing the demand for food (Campos *et al.,* 2004). A great deal of research has focused on the influence of drought stress on crop development and productivity. It has been demonstrated that plants vary in their response to water deficit, depending on the severity of the stress and the developmental stage at which stress to the plant takes place (Kareem *et al.,* 2019; Shavkiev *et al*., 2023).

Legume crops, such as mung beans (*Vigna radiata* L), come second only to cereal crops in terms of importance. About one-third of human dietary protein is derived from grain legumes (Htwe *et al.,* 2019). Mung beans can be used in various forms and are used as a whole snack and as bean sprouts or bean noodles. They have important biological functions, such as detoxification, the reduction of cholesterol, and antitumour and anti-inflammatory activities (Du *et al.,* 2018), and contain high levels of vitamins, minerals, proteins, and essential amino acids (Zhong *et al.,* 2012). They constitute a significant part of the human diet and are also used as animal feed since the seeds contain high levels of protein (240 $g\cdot kg^{-1}$) and carbohydrates (630 $g\cdot kg^{-1}$). They are more easily digestible than other legumes, and they cause less flatulence and are better tolerated by children(Bangar *et al.,* 2019; Nair *et al.,* 2013).

Zare et al. (2013) observed a 51% to 85.50% yield reduction due to drought stress in the mungbean. The flowering and the post-flowering stages have been found to be more sensitive than the vegetative stage in drought (Ranawake *et al.,* 2011).

Yield is a complex character, which is highly affected by the genotype and its interaction with environmental factors (Singh *et al.,* 2014; Mehandi *et al.,* 2015; Singh *et al.,* 2015; Singh *et al.,* 2016). Simultaneously, it also depends upon the expression of different morpho-physiological functions. These morpho-physiological processes are highly affected by drought stress, which exhibits an impact on yield. The characteristics like plant height, leaf size, pod filling index, seed weight, root architecture and crop yield are significantly reduced under drought stress conditions in mungbean and other legumes (Khan *et al.,* 2015). Drought stress also greatly impacts the nutrient uptake by plant root systems along with water (Da Silva *et al.,* 2011; Bista *et al.,* 2011) due to reduced root growth in drought conditions. Furthermore, symbiotic association plays an important role in the nutrient relations of legumes, which also affects nitrogen-fixing ability and plant growth. Due to interactive effects, the nutrient relations are more complicated; therefore, this requires detailed research at the molecular level. Hence, there is an utmost need to develop drought-tolerant varieties to improve crop productivity to ensure farmers' nutritional and livelihood security, especially under the changing climate. The diverse mechanisms such as drought escape, drought avoidance, and drought tolerance are involved in the adoption of drought stress that enables the plants to survive, accumulate dry matter and produce seeds (Levitt *et al.,* 1980).

Crops mainly affected by drought in the country are those extensively cultivated in the semi-arid areas. Among these crops, mung bean (*Vigna radiata*), a legume crop rich in protein, is one of them. The relative yield performance and drought-related indices of genotypes under drought-stressed and non-drought-stressed conditions were used as criteria to identify durum wheat genotypes tolerant to moisture scarcity (Mohammadi *et al.,* 2010). These indices have been employed in the selection of drought-tolerant genotypes of different crop types. Although a number of indices are available to measure the tolerance of crops to drought, the geometric mean productivity (GMP) (Fernandez, 1992) is considered among the best indicators as it less sensitive to extreme values. Stress tolerance index (TOL) which is based on the differences in yields measured under non-stress (Yp) and stress (Ys) conditions (Rosielle and Hamblin, 1981) is also extensively used.

Other widely applied drought-related indices include the stress susceptibility index (Fischer and Maurer, 1978), yield index (Lin *et al.,* 1986), yield stability index (Bouslama and Schapaugh, 1984), stress intensity (Fernandez, 1992), stress susceptibility percentage index (Moosavi *et al.,* 2008), stress tolerance index (Fernandez, 1992), drought intensity index (Beebe et al., 2013), relative drought index (Fischer *et al.,* 1998), mean relative performance (Hossain et al., 1999), harmonic mean (Dadbakhch *et al.,* 2011), and yield stability index (Bouslama and Schapaugh, 1984). Although several types of indices are implemented to determine the performance of crops under drought conditions, these indices were not exploited in the mung bean improvement program in Uzbekistan. Since mung bean is extensively cultivated in drought-prone areas in the country, it is necessary to apply key indices to assess the performance of mung bean germplasm to drought. Hence, the major goal of this study was to determine the performance of mung bean germplasm to drought using selected indices. In addition, the study is aimed at identifying the best drought-related index to be used in screening for drought tolerance in mung bean.

The purpose of the research is to create new high-yielding mung bean cultivars well adapted to the local soil and climate conditions, to assess their resistance to water deficit.

Material and methods

Description of the Study Area

The field experiments were carried out in 2022-2023 on the field site Durmon of the regional experimental base of the Institute of Genetics and Biology of Experimental Plants of the AS UzR, located in the Kibray district of the Tashkent region. This land plot is located 0.5 km northeast of the city of Tashkent, 41^{0}20 north latitude, 69^{0}18 east longitude, in the upper reaches of the Chirchik River, at an altitude of 398 meters above sea level. The soil type of the center is grey soil (Shavkiev *et al*., 2022).

The soil of the experimental field is low-humus, typical sierozem, medium-sandy in texture. The terrain is slightly sloping and non-saline. Groundwater is deep (7-8 m). The climate is highly variable, summer (June, July, August) is characterized by high heat, and winter (especially December and January) is characterized by a sharp drop in air temperature. The sunny days are 155-165 days, the frost-free period is 200-210 days. The precipitation falls in autumn, winter and spring, and summers are dry. This requires artificial irrigation of mungbean.At the Dorman experimental station, a large daily temperature change is observed - the nighttime absolute minimum in May is +0.50^{0}C and in June +3-15^{0}C, the average long-term temperature is +13.40C. The coldest month is January with an average air temperature of -1.7^{0}C, and the warmest month is July (+26.6^{0}C). The average annual precipitation is 340-400 mm. Snow cover is extremely unstable, not permanent, and is often absent even during the coldest times of the year. In many places, though not every year, temporary snow cover is observed in December and January. Agro-technical measures on the experimental plots were carried out in the order adopted in the experimental farm of the Institute of Genetics and Plant Experimental Biology: in spring, the plots were cleared of wheat and ploughed to a depth of 35 cm. In spring, at moderate air and soil temperatures, fertilizers and soil pulverization were applied in order to retain moisture in the soil and destroy growing weeds.

Experimental Design and Procedures

The crop requires intensive irrigation throughout the vegetative period. Mung bean is irrigated by following a 1–2–1 (pre-flowering flowering-pod opening) sequence with 1000 m^3 /hm^2 of water applied before flowering, two applications of 1500 m^3 /hm^2 each during flowering, and 1000 m^3 /hm^2 before the pod opening phases. This sequence is an optimal irrigation protocol widely used in legume production in Uzbekistan. Soil moisture also contributes to water during seed germination. A developed irrigation protocol for water deficit conditions followed a 1–1–0 sequence with 1000 m^3 /hm^2 of water applied before flowering and one application of 1200 m^3 /hm^2 of water each during flowering. For watering plants during the growing season, agro-technical activities have been carried out. Mineral fertilizers were applied before planting by top dressing 3 times during the growing season (1st top dressing at the beginning of pod forming, the 2nd was during mass pod forming, the 3rd was during flowering). The annual norm of mineral fertilizers in pure state made up N-80 kg/ha, P -80 kg/ha and K-30 kg/ha.

Sowing was carried out in the third decade of May according to the scheme 60x8x1 on the marked fields. The seeds are planted in the ground to a depth of 4-5 cm. They are sown in 3 replications, 2 rows in each replication, and 25 seedbeds in each replication. The selection number of varieties and areas was 50 plants. Inter-row work and weeding were carried out in combination with irrigation.

The experiment was laid out using a 6 × 10 alpha lattice design replicated twice. The genotypes were grown under two field conditions, namely moisture-stressed and non-moisture-stressed. Under non-moisture-stress conditions, experimental plants were weekly irrigated until the physiological maturity stage, while under the moisture-stressed regime, irrigation water was withheld from the flower bud initiation to the physiological maturity stage.

Experimental materials

As an object of the study the species of mung bean belonging *Vigna radiata* L. Wilzeckt. the local varieties Durdona, Barqaror, Marjon, Andijon-1, Zilola, Ishonch, Baraka, and local lines L-22, L-88, L-92 were used.

Data Collection

In the experiment, Yield index, yield stability index, stress intensity, stress susceptibility percentage index, stress susceptibility index, stress tolerance index, drought intensity index, tolerance index, geometric mean productivity, relative drought index, mean relative performance, harmonic mean, mean productivity and sensitivity drought indices were determined. The drought tolerance indices were quantified using equations indicated in Table 1.

Table 1. Drought tolerance indices with their equations

Drought Tolerance Indices	Equation	Reference
Yield Index (YI)	$Ys/ \bar{Y}s$	Lin *et al.*, 1986
Yield stability index (YSI)	Ys / Yp	Bouslama and Schapaugh, 1984
Stress Intensity (SI)	$(Yp-Ys)/ \bar{Y}p$	Fernandez, 1992
Stress susceptibility percentage index (SSPI)	$[Yp-Ys /2(\bar{Y}p)]\times100$	Moosavi *et al.*, 2008
Stress Susceptibility Index (SSI)	$(1-(Ys/Yp))/(1-(\bar{Y}s/ \bar{Y}p))$	Fischer and Maurer, 1987
Stress tolerance index (STI)	$(Yp *Ys) / (\bar{Y}p) 2$	Fernandez, 1992
Drought intensity index (DI)	$1-(Ys/Yp)$	Beebe *et al.*, 2013
Tolerance index (TOL)	$Yp - Ys$	Rosielle and Hamblin, 1981
Geometric mean productivity (GMP)	$\sqrt{(YpxYS)}$	Fernandez, 1992
Relative drought index (RDI)	$(Ys/Yp)/ (\bar{Y}s / \bar{Y}p)$	Fischer *et al.*, 1998
Mean relative performance (MRP)	$(Ysi / \bar{Y}s) + (Ypi / \bar{Y}p)$	Hossain *et al.*, 1999
Harmonic Mean (HM)	$2 x (Yp x Ys) / (Yp + Ys)$	Dadbakhsh *et al.*, 2011
Mean productivity(MP)	$(Ys+Yp)/2$	(Rosielle and Hamblin, 1981
Sensitivity drought index (SDI)	$(Yp-Ys)/Yp$	Farshadfar and Javadinia, 2011

Where; Ys, Yp, $\bar{Y}s$, and $\bar{Y}p$ represent yield under stress, yield under non-stress for each genotype and yield mean in stress and non-stress conditions for all genotypes, respectively.

Data Analyses

The study recorded data on all the parameters for 10 competitive plants in each genotype, and calculated crop yield per plant. Data were statistically analyzed using appropriate ANOVA for Statsgraphs 18. A comparison of means by using multiple range tests at the probability levels of 0.05, 0.01, and 0.001 was calculated (Steel and Torrie, 1984).

Results

In the experiment, a yield index in field conditions was studied in 10 mungbean genotypes, in which the yield index in the Ishonch variety was recorded at 1.83 at the highest and on the L-59 and L-92 lines (0.52 and 0.52, respectively) at the lowest index. In the case of the yield stability index, however, the Barqaror variety of mungbean was found at 0.80 at the highest and 0.29 at the L-59 line at the lowest. At the traits of stress intensity, the L-59 line was detected at 0.94 at the highest and at 0.13 at the lowest at the L-92 line. In the stress susceptibility percentage index and stress susceptibility index, the Barqaror and L-92 genotypes recorded at the lowest rate (7.0%; 6.56%, and 0,42; 0,52 respectively), while the highest recorded (46.87% and 1,50 respectively) in the L-59 line. The highest stress tolerance index was recorded in the Ishonch variety at 1.22 and the lowest at 0.19 in the L-92 line. The drought intensity index was found to be 0.20 at the lowest in the Barqaror variety and 0.71 at the highest in the L-59 line.

The Tolerance index was found to be 20.19 at the highest in the L-59 line and Barqaror and the L-92 genotypes (3.02 and 2.83, respectively) at the lowest. Geometric mean productivity was 23.82 at the highest in the Ishonch variety in 10 mungbean genotypes and 9.43 at the lowest in the L-92 line. The relative drought index is 1.52 at the highest in the Barqaror variety and 0.55 at the lowest in the L-59 line. Estimates of the mean relative performance, harmonic mean and average and mean productivity indices were in the Ishonch variety at the highest indicators (3.10, 23.56 and 24.06, respectively) and the lowest in the L-92 line (1.23, 9.32 and 9.53, respectively). The sensitivity drought index was noted to be 0.20 at the lowest in the Barqaror variety and 0.71 at the highest in the L-59 line.

Table 2. Indicators of water deficit tolerance in Mung Bean (Vigna radiata L.) genotypes.

	YI	YSI	SI	SSPI	SSI	STI	DI	TOL	GMP	RDI	MRP	HM	MP	SDI
Durdona	0,97	0,42	0,69	34,65	1,21	0,61	0,58	14,93	16,78	0,81	2,16	15,33	18,37	0,58
Zilola	1,28	0,53	0,60	29,80	0,99	0,85	0,47	12,84	19,81	1,01	2,54	18,85	20,83	0,47
Turon	0,76	0,43	0,52	26,23	1,19	0,37	0,57	11,30	13,06	0,82	1,68	11,99	14,23	0,57
Barqaror	1,05	0,80	0,14	7,00	0,42	0,38	0,20	3,02	13,32	1,52	1,75	13,23	13,40	0,20
Baraka	0,72	0,47	0,42	20,95	1,10	0,30	0,53	9,03	11,82	0,90	1,52	11,05	12,66	0,53
Ishonch	1,83	0,75	0,32	15,75	0,52	1,22	0,25	6,79	23,82	1,44	3,10	23,58	24,06	0,25
L-59	0,72	0,29	0,94	46,87	1,50	0,50	0,71	20,19	15,23	0,55	2,04	12,69	18,27	0,71
L-88	1,14	0,57	0,45	22,34	0,90	0,62	0,43	9,63	16,96	1,09	2,18	16,32	17,63	0,43
L-92	0,72	0,74	0,13	6,56	0,54	0,19	0,26	2,83	9,43	1,42	1,23	9,32	9,53	0,26
Andijon 1	0,82	0,44	0,55	27,61	1,18	0,42	0,56	11,90	13,95	0,83	1,80	12,83	15,16	0,56

Note: Yield Index (YI), Yield stability index (YSI), Stress Intensity (SI), Stress susceptibility percentage index (SSPI), Stress Susceptibility Index (SSI), Stress tolerance index (STI), Drought intensity index (DI), Tolerance index (TOL), Geometric mean productivity (GMP), Relative drought index (RDI), Mean relative performance (MRP), Harmonic Mean (HM), Mean productivity(MP), Sensitivity drought index (SDI).

The agglomeration schedule shows which observations were combined at each stage of the clustering process. For example, in the first stage, observation 3 was combined with observation 10. The distance between the groups when combined was 0,270567. It also shows that the next stage at which this combined group was further combined with another cluster was stage 2.

Table 3. Cluster analysis of drought resistance indices of Mung Bean genotypes

Stage	*Combined*	*Combined*	*Distance*	*Previous Stage*	*Previous Stage*	*Next*
	Cluster 1	*Cluster 2*		*Cluster 1*	*Cluster 2*	*Stage*
1	3	10	0,270567	0	0	2
2	3	5	1,06593	1	0	7
3	2	8	2,06455	0	0	6
4	4	9	3,22423	0	0	8
5	1	7	4,57687	0	0	6
6	1	2	7,24702	5	3	7
7	1	3	10,3359	6	2	9
8	4	6	14,8516	4	0	9
9	1	4	21,5868	7	8	0

According to the cluster analysis, it was divided into 3 groups according to water deficit resistance, susceptibility and moderate resistance. It was found that the genotypes of Barqaror, L-92, and Ishonch are resistant to water deficit, Turon, Andijan, and Baraka genotypes are moderately resistant, and Durdona, L-59, Zilola, and L-88 genotypes are susceptibility.

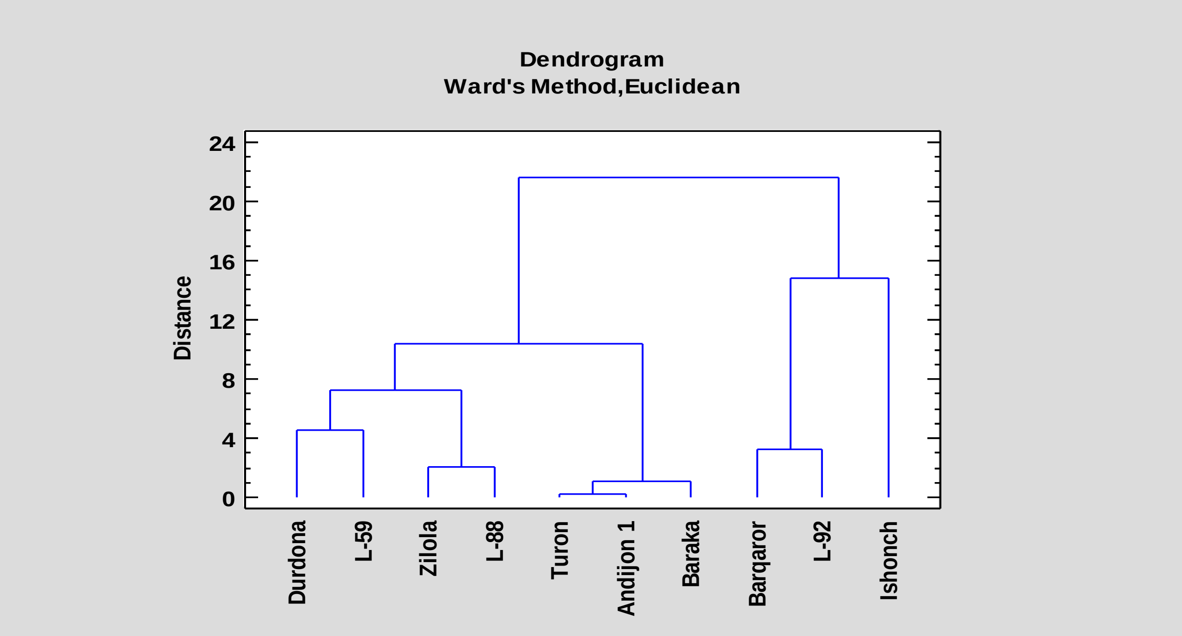

Figure 1. Ward's method cluster analysis of drought resistance indices of Mung Bean genotypes

Discussion

The stress tolerance index (STI), which is normally used to identify genotypes that produce high yields under both stressed and non-stressed conditions identified the same genotypes as drought-susceptible and drought-tolerant. Similar findings were earlier reported for different crops (Fernandez 1992; Mohammadi *et al.*, 2010). Based on the stress susceptibility index (SSI), Barqaror and Ishonch are the most drought-tolerant while Durdona and L-59 is the most drought-susceptible genotype. This shows that genotypes with the lowest SSI values are considered drought-tolerant and are high yielders whereas; genotypes with the highest SSI values are drought-susceptible. In conclusion, those genotypes with the highest scores for stress susceptibility index (SSI), stress intensity (SI) and tolerance index (TOL) could be considered as drought susceptible genotypes while those genotypes with the highest values of the harmonic mean (HM), yield index (YI), yield stability index (YSI), stress tolerance index (STI), and geometric mean productivity (GMP) could be desirable genotypes in moisture stress conditions. Moreover; stress tolerance index (STI), yield index (YI), harmonic mean (HM), geometric mean productivity (GMP), and mean relative performance (MRP) are convenient indices to select high-yielding mung bean genotypes in both moisture-stressed and non-stress conditions.

Cluster analysis revealed that the 10 mung bean genotypes used in the present study were grouped into five distinct clusters using 3 drought tolerance indices and seed yield (Figure 1). Cluster I comprised seven high-yielding genotypes under moisture-stressed and non-moisture-stressed conditions. In most cases, the genotypes had the highest values of stress tolerance index (STI), harmonic mean (HM), yield index (YI), and mean relative performance (MRP). This shows that these genotypes perform consistently under both water regimes.

Conclusions

Drought tolerance index indicators were determined based on the cluster analysis for water deficit tolerance. In the field conditions of the Tashkent region, among the 10 genotypes of mungbean crops, it was found that the genotypes of Ishonch and Barqaror are resistant to water deficit and Turon, Andijan, and Baraka genotypes are moderately resistant, and Durdona, L-59, Zilola, and L-88 genotypes are susceptibility.

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