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Phenotypic Characteristics of Lablab Accessions Compared Between Water Stressed and Non-Stressed Seedling Phases to Determine Stress Tolerant Accessions in Semi-arid Conditions

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Abstract

Drought poses a severe threat to agriculture, particularly in sub-Saharan Africa (SSA) where the effects of climate change are most noticeable. There are few crop' species that are able to resist drought stress. Despite the fact that Lablab is a multipurpose crop with high potential on drought tolerance, little research has been conducted to evaluate the crop's early responses to the drought stress in arid and semi-arid conditions. This study therefore aimed to identify stress-tolerant Lablab accessions by analyzing their phenotypic seedling traits under different moisture regimes (MR) in semi-arid conditions. In the study, seventeen potential accessions were subjected to the water stressed (S/ST) and non-stressed (NS) experiments in screen-house after germination. Two checks were considered in the experiments. Throughout the three repeated experiments, data collection involved several morpho-physiological traits including plant height, root length, shoot and root biomass, and relative water content (RWC), monitored every two days since withdrawal of water to the experiment. Seed weight (SW) was measured in triplicate before the beginning of the experiment. The Bartlett's and Levene's tests demonstrated ($p > 0.05$) normal distribution of the data. Using Gen-Stat and R software, ANOVA and post-hoc Tukey tests ($p \leq 0.05$) were performed to examine the differences between the accessions across the seedling traits, days and MR. The findings revealed the significant difference ($p < 0.05$) in the traits in relation to the accessions, MR, and their interactions. Variation of the accessions on different traits as compared between the ST and NS experiments at day 7 was also proven significant. Through the ranking method, D349, D352, D363, D359, D147, HA4 and D348 were selected as the best drought tolerant (DT) accessions at seedling stage recommended for further assessment towards releasing the DT-high yield varieties potential in semi-arid conditions such as the central zone of Tanzania.

Keywords: *Dolichos Lablab; Drought tolerance; Water stress; Morpho-physiological traits, Seedling stage*

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Introduction

Shortage of food is expected in many countries especially, in sub-Saharan Africa (SSA) due to an increase in drought stress (Lottering *et al.,* 2021). As such, food production sustainability is identified as a critical step that requires prompt intervention, particularly in the present face of climate change (Ngcamu and Chari, 2020). Although few crop species do well in dry environments, identifying them, along with knowledge on their responses to drought stress, could hasten the scientific effort to produce drought-tolerant (DT) varieties, potentially for the future stability of food security and income (Hossain *et al.,* 2021; Missanga *et al.,* 2021).

Lablab (*Lablab purpureus* L. Sweet) is an essential leguminous crop with multiple range of benefits (Miller *et al.,* 2018). First, it is a human food utilized as dry or green beans, leaf vegetable, and tender pods while its flour baked into processed materials such as biscuits (Missanga *et al.,* 2023b). It is also a feeding resourceful crop for livestock especially as fresh foliage, hay or silage (Wangila *et al.,* 2021). As enriched with different food nutrients especially protein (about 30%), Lablab has a great contribution to the elimination of nutrient deficient diseases such as malnutrition (Shubha *et al.,* 2024). Second, Lablab is an important cover crop and green manure with high ability of nitrogen fixation (about 200 Kg N ha^{-1}) (Naeem *et al.,* 2020). Third, Lablab is a potential drought resilient crop that plays a great role in sustainability of food security. This crop is mainly grown in the tropical and sub-tropical regions in a wide range of rainfall (200-2500 mm) and temperature (18 °C - 35 °C) (Nord *et al.,* 2020; Maass, & Chapman, 2022). This climatic condition differentiates Lablab from other crops that are unable to survive in the little amount of rainfall and high temperature. In a situation where crops have been lost from the field in the dry farming systems due to persistent drought, farmers' food and income have been depending much on products harvested from drought tolerant (DT) crops especially, Lablab. This crop is even sold higher than other legumes in northern Tanzania and central Kenya (Missanga *et al.,* 2023a).

Despite such benefits, Lablab has been neglected in many countries in Africa including Tanzania especially, after introduction of *Phaseolus* beans. Therefore, Lablab lost its popularity in many areas except in few parts of northern regions of Tanzania and Kikuyu area in central Kenya (Miller *et al.,* 2018). This decline of Lablab production in Africa caused genetic erosion of the crop and loss of farmers' knowledge about it (Nord *et al.,* 2020; Maass and Chapman, 2022). In many areas including Tanzania, Lablab production involved few farmers in small and scattered areas using their own local cultivars. These cultivars lacked improved traits such as drought tolerance (Missanga *et al.,* 2023b).

To increase economic production of Lablab through its various uses, particularly during this period of persistent drought stress, drought resilient Lablab accessions with improved traits must be developed. These improved Lablab accessions are still lacking in many countries' dry farming systems, including Tanzania. Their availability would benefit farmers in arid and semi-arid areas such as the central zone of Tanzania which experiences high effect of drought stress in the country. However, choosing the best crop varieties at early stages would guarantee their best performance at later stages (Lu *et al.*, 2022). Therefore, this study focused on characteristics of water ST and NS Lablab accessions at the seedling stage to select the best drought resilient accessions for further evaluation towards developing DT - high yield varieties.

Materials and Methods

Plant material and experimental design

Seventeen potential Lablab accessions selected from different countries; D363 from Uganda; D348, D352 (Eldoret KT Cream), D349 (Eldoret KT Maridadi) and D359 (ILRI. 14491) from Kenya; D30 and D28 from Bangladesh; D66 from Uzbekistan; D147 and D250 from Ethiopia; D137, D258, D257 and HA4 from India; D55 from Cambodia; D26 from Lao Peoples' Democratic Republic; and D311 (Kondoa White) from Tanzania were evaluated for drought tolerance through the three repeated water stress and non-stressed pot experiments i.e. experiments with two different moisture (water) regime (MR) in screen house at the College of Natural and Mathematical Sciences (CNMS), University of Dodoma (UDOM), Tanzania. UDOM lies in the central zone of Tanzania [Longitude: 35° 49' 16" East (E); Latitude: 6° 13' 18" South (S) and Elevation: 1245m above sea level (asl)] which has semi-arid characteristics with high temperature and little rainfall. The screen house was covered by plastic (nylon) materials except at the base of the house. Every MR of the experiment had two checks i.e. D363 (NMD 19) and D348 (NMD 20) - the commercial Lablab varieties in the country.

Experimental process and data collection

The experiment began with measurements of 100 Seed Weight (SW) in triplicates for each Lablab accession. Then, the seeds of each accession were surfaces sterilized by *submerging them into 70% ethanol for few minutes followed by rinsing them with large volume of distilled water. The overnight-soaked seeds (three seeds per accession) were sown in the pots containing top soil and sand soil (1:1 w/w) and irrigated with tape water daily for a period of two weeks until their germination. Only two seedlings per accession were left to grow in the pot for the data set and each traits considered average scores between them.* Data collection involved daily minimum and maximum temperature (^oC) and humidity (%) monitored in the screenhouse throughout the experiment using digital sensor as well as several morpho-physiological traits of each accession including plant height, and root length (cm), shoot and root biomass (g) and relative water content (RWC%) monitored four times in each experimental cycle at two days interval since the withdrawal of water to the experiment i.e. 1, 3. 5, and 7 days after stress (DAS) as per method improved from D'souza and Devaraj (2011); and Ravelombola *et al.* (2020). D*etermination of the RWC% was completed through measurements of fresh weight (FW), turgid weight (TW), and dry weight (DW) of each leaf samples through a uniform disc of about 3 cm diameter. Immediately after harvesting of leaves. the FW was measured at room temperature at 25 ^0C while TW was determined in distilled water at 25 ^0C for 4 hours (h). The DW was oven-dried at 80 ^0C for 24 h before its determination. The RWC was finally estimated through the following equation. RWC = [(FW – DW)/ (TW – DW)] x 100 as described by D'souza and Devaraj (2011).* This experiment was conducted during the dry season.

Data analysis

Mean for the minimum and maximum temperature and humidity collected in the screen-house were computed along every experimental cycle using MS excel. Before analysis of the seedling data so to examine the variations between the accessions in terms of their performance across the MR at day 7, their normality was examined using the Bartlett's and Levene's tests at p = 0.05. The variations in seedling traits were then analyzed through ANOVA and post-hoc Tukey test ($p \leq 0.05$) using Gen Stat (version 12) and R (version 4.1.1: 2024-26-04) software. The ranking method was finally used to select the best accessions based on good performance with only a minor difference in performance between the NS and TS experiments.

Results

Environmental parameters in the screen house

Minimum and maximum temperatures in the screen house ranged between 23.8 ^oC - 24.5 ^oC, and 36.6 ^oC - 38.9 ^oC, with 24.1 ^oC and 37.7 ^oC recorded as their mean values, respectively. Minimum and maximum humidity had a range of 61.8% - 62.9% and 29.1% - 33.6% with 62.4% and 30.6% recorded as their mean values, respectively.

Variation among the accessions in seedling traits across the moisture regimes

The significant difference ($p \leq 0.05$; **, $p < 0.001$; ***, $p < 0.0001$) was observed among the seedling traits across the accessions, MR, their interactions and other experimental factors (Table 1). Moreover, significant variation among the accessions on different seedling traits as compared between the ST and NS experiments at day 7 [plant height and root length (Table 2), shoot biomass and root biomass (Table 3) as well as RWC% and 100 SW (Table 4)] was demonstrated on Figure 1 (plant height), Figure 2 (root length), Figure 3 (shoot biomass), Figure 4 (root biomass) and Figure 5 (RWC). All the studied seedling traits in NS experiments increased rapidly in amount and their growth, especially at day 5 and day 7. This was in contrast to the ST experiments, where all the traits showed somewhat a slower growth at days 5 and day 7, except in root length (Table 2; Figure 2). Most of the accessions showed relative longer increase in root length in the ST experiments than in the NS experiment, particularly for accessions HA4, D311 and D26. However, the best DT accessions were those that showed good performance at each trait with little variations between the NS and TS experiments. The final selection for the best accessions considered 100 SW and the accessions with > 25.0 (g) of 100 SW (Table 4) were selected for the ranking process.

Based on the ranking method (Table 5), D349, D352, D363, D359, D147, HA4 and D348 were selected as the best DT Lablab accessions potential in arid and semi-arid conditions.

Table 1

Variation in plant seedling traits across the accessions, moisture regimes and other factors

SN	Trait	Source of Effect	DF	SS	MSS	F	*P*
1	Plant height	Accessions	16	73.10	4.569	30.272	< 2e-16 ***
		MR	1	31.52	31.519	208.827	< 2e-16 ***
		Accession x MR	16	10.05	0.628	4.161	2.05e-07 ***
		Residuals	374	56.45	0.151		
2	Root length	Accession	16	6134	384.4	13.733	< 2e-16 ***
		MR	1	1253	1253.4	44.895	7.66e-11 ***
		Accession x MR	16	1612	100.8	3.609	4.00e-6 ***
		Residuals	374	10441	27.9		
3	Shoot Biomass	Accession	16	75.35	4.71	16.522	< 2e-16 ***
		MR	1	96.67	96.67	339.162	< 2e-16 ***
		Accession x MR	16	23.01	1.44	5.044	1.66 e-09 ***
		Residuals	374	106.60	0.29		
4	Root Biomass	Accession	16	32.2	2	20.042	< 2e-16 ***
		MR	1	324.7	324.7	3235.568	< 2e-16 ***
		Accession x MR	16	11.7	0.7	7.276	8.67e-15 ***
		Residuals	374	37.5	0.1		
5	RWC	Accession	16	2650	165.63	8.587	< 2e-16 ***
		MR	1	66	66.24	3.434	0.00016
		Accession x MR	16	369	23.06	1.196	0.000268
		Residuals	374	7214	19.29		

Table 2

Variation of Lablab accessions on plant height and root length as compared between the ST and NS experiments at day 7

S/N	A/C	Plant height (cm)								Root length (cm)							
		NS				ST				NS				ST			
		Mean		SE		Mean		SE		Mean		SE		Mean		SE	
1	D 147	5.43	±	0.19	ab	4.50	±	0.00	a	35.67	±	0.33	ab	36.67	±	1.01	ab
2	D 359	5.50	±	0.40	ab	4.50	±	0.00	a	34.67	±	2.40	abc	34.87	±	1.86	bcd
3	D 348	5.30	±	0.06	abc	4.50	±	0.00	a	33.33	±	1.33	abc	33.50	±	0.29	bc
4	D 349	5.97	±	0.09	a	4.50	±	0.00	a	38.67	±	1.86	a	39.00	±	0.58	a
5	D 363	5.83	±	0.17	a	4.40	±	0.06	a	35.00	±	1.53	abc	35.17	±	0.88	b
6	HA4	5.17	±	0.23	abcd	4.33	±	0.03	ab	33.67	±	0.67	abc	35.83	±	0.17	bc
7	D 55	5.07	±	0.03	abcd	4.07	±	0.07	bc	32.00	±	2.31	abc	30.33	±	0.33	cdef
8	D 352	5.97	±	0.20	a	4.33	±	0.03	ab	32.00	±	1.53	abc	33.17	±	1.01	bc
9	D 311	4.57	±	0.23	bcde	4.10	±	0.06	bc	32.33	±	1.76	abc	34.20	±	0.44	b
10	D 26	4.03	±	0.15	e	3.73	±	0.07	de	23.33	±	0.67	d	25.67	±	0.88	def
11	D 250	4.37	±	0.19	cde	4.00	±	0.10	cd	30.00	±	2.31	bcd	30.83	±	0.73	cdef
12	D 137	4.40	±	0.10	cde	3.87	±	0.03	cde	23.67	±	1.20	d	24.20	±	0.76	cd
13	D 257	4.23	±	0.18	de	3.87	±	0.03	cde	27.50	±	0.76	cd	27.60	±	0.50	def
14	D 28	4.23	±	0.33	de	3.63	±	0.07	e	24.00	±	1.53	d	24.67	±	0.88	ef
15	D 66	4.53	±	0.09	bcde	3.63	±	0.07	e	29.00	±	0.58	bcd	29.33	±	0.88	def
16	D 258	4.33	±	0.09	cde	3.73	±	0.07	de	31.20	±	0.58	bcd	31.00	±	0.58	cde
17	D 30	5.03	±	0.03	abcde	3.73	±	0.03	de	24.00	±	0.00	d	25.17	±	1.17	cdef
*Selection of the best accessions		≥ 4.5 for NS and ≥ 4.0 for ST: D349; D352; D363; D359; D147; D348; HA4; D55; D311; D250								≥ 30 for NS and ST: D349; D147; D363; D359; HA4; D348; D311; D352; D55; D250; D258							

Note: NS: Non-stressed experiment; ST: Stressed experiment; SE: Standard error

Table 3

Variation of Lablab accessions on shoot biomass and root biomass as compared between the ST and NS experiments at day 7

S/N	A/C	Shoot biomass (g)								Root biomass (g)							
		NS				ST				NS				ST			
		Mean		SE		Mean		SE		Mean		SE		Mean		SE	
1	D 147	6.06	±	0.58	a	5.04	±	0.06	a	2.99	±	0.17	ab	2.18	±	0.04	ab
2	D 348	5.20	±	0.21	ab	3.20	±	0.04	cd	3.19	±	0.06	a	2.15	±	0.04	ab
3	D 349	5.16	±	0.13	ab	3.55	±	0.11	bc	3.15	±	0.17	ab	2.00	±	0.01	ab
4	D 363	5.11	±	0.12	abc	4.05	±	0.12	a	2.99	±	0.13	ab	1.76	±	0.01	cd
5	D 352	4.93	±	0.13	abcd	3.47	±	0.06	bc	3.05	±	0.16	ab	2.18	±	0.04	ab
6	D 359	4.86	±	0.41	abcd	3.92	±	0.02	abc	3.21	±	0.11	a	2.37	±	0.03	a
7	HA4	4.75	±	0.27	abcd	3.87	±	0.05	bc	3.03	±	0.16	ab	2.36	±	0.01	a
8	D311	4.62	±	0.17	bcd	3.91	±	0.04	abc	2.90	±	0.07	ab	2.06	±	0.12	bc
9	D 55	4.52	±	0.41	bcd	3.65	±	0.15	ab	2.97	±	0.07	ab	1.80	±	0.05	de
10	D 28	4.07	±	0.14	bcd	3.51	±	0.09	bc	2.34	±	0.04	b	1.32	±	0.01	ef
11	D 250	4.06	±	0.05	bcd	3.00	±	0.06	de	2.97	±	0.13	ab	1.62	±	0.02	ef
12	D 258	3.95	±	0.21	bcd	2.51	±	0.06	ef	2.33	±	0.30	b	1.39	±	0.01	ef
13	D 66	3.70	±	0.17	bcd	2.83	±	0.03	de	2.41	±	0.03	ab	1.30	±	0.02	f
14	D 257	3.70	±	0.21	bcd	2.60	±	0.10	ef	2.45	±	0.32	ab	1.39	±	0.06	ef
15	D 137	3.63	±	0.27	cd	2.85	±	0.18	de	2.35	±	0.12	b	1.49	±	0.05	ef
16	D 30	3.59	±	0.35	d	2.26	±	0.06	f	2.34	±	0.17	b	1.83	±	0.15	cd
17	D 26	3.53	±	0.43	d	3.39	±	0.08	bc	2.53	±	0.14	ab	1.28	±	0.01	f
*Selection of the best accessions		≥ 4.0 for NS and ≥ 3.0 for ST: D147; D348; D349; D363; D352; D359; HA4; D311; D55; D28; D250								≥ 2.5 for NS and ≥ 1.5 for ST: D359; D348; D349; D352; HA4; D147; D363; D250; D55; D311							

Note: NS: Non-stressed experiment; ST: Stressed experiment; SE: Standard error

Table 4

Variation of Lablab accessions on RWC and 100 SW as compared between the ST and NS experiments at day 7

S/N	A/C	RWC (%)								100 SW
		NS				ST				
		Mean		SE		Mean		SE		
1	D 349	67.33	±	1.45	a	59.20	±	0.99	ab	28.2±0.98
2	D 147	65.83	±	1.01	ab	58.50	±	1.76	ab	33.1±1.45
3	D 348	64.83	±	1.64	ab	58.17	±	2.11	ab	30.2±1.23
4	D 55	64.45	±	2.40	ab	57.67	±	2.96	ab	27.1±1.43
5	HA4	64.67	±	1.20	ab	59.73	±	1.67	ab	27.4±1.45
6	D 352	63.68	±	0.33	ab	60.50	±	0.50	a	26.7±1.23
7	D 363	62.83	±	2.13	ab	58.83	±	2.92	ab	28.1±1.33
8	D 250	62.67	±	2.60	ab	55.00	±	2.31	ab	25.0±0.33
9	D 359	62.33	±	1.33	ab	60.07	±	2.67	a	31.7±1.23
10	D 28	60.60	±	1.76	ab	58.67	±	3.67	ab	22.3±0.57
11	D 66	58.33	±	3.48	ab	53.67	±	3.18	ab	22.2±0.96
12	D 258	58.00	±	2.00	ab	54.67	±	2.91	ab	21.7±0.86
13	D 311	58.00	±	3.21	ab	57.00	±	2.00	ab	26.5±1.09
14	D 257	57.67	±	1.45	ab	49.67	±	3.89	bcd	23.5±0.18
15	D 137	57.33	±	1.20	ab	54.50	±	3.25	abc	23.8±0.24
16	D 30	57.33	±	2.19	ab	53.33	±	2.18	abc	21.2±0.11
17	D 26	56.67	±	0.67	b	51.00	±	3.93	bcd	25.8±1.39
*Selection of the best accessions		≥ 58.0 for NS and ≥ 55.0 for ST: D349; D147; D348; D55; HA4; D352; D363; D250; D359; D28; D311								≥ 25: D147; D359; D348; D349; D363; HA4; D55; D352; D311; D26; D250

Note: NS: Non-stressed experiment; ST: Stressed experiment; RWC: Relative water content; SW: Seed weight; SE: Standard error

Tables 5

Ranking of the best DT Lablab accessions based on their performance at seedling stage

S/N	A/C	Seed color	Plant height	Root length	Shoot biomass	Root biomass	RWC %	100 SW	Ranking process	
			P	P	P	P	P	P	Summation and average	Rank
1	D349	Black	1	1	3	3	1	4	(1+1+3+3+1+4)/6=2	1
5	D147	Brown	5	2	1	6	2	1	(5+2+1+6+2+1)/6=3	2
6	D348	Black	6	6	2	2	3	3	(6+6+2+2+3+3)/6=3	2
3	D363	Red	3	3	4	7	7	5	(3+3+4+7+7=5)/6=5	4
4	D359	Brown	4	4	6	1	9	2	(4+4+6+1+9+2)/6=5	4
2	D352	Cream	2	8	5	4	6	8	(2+8+5+4+6+8)/6=6	6
7	HA4	Cream	7	5	7	5	5	6	(7+5+7+5+5+6)/6=6	6
8	D55	Brownish	8	9	9	9	4	7	(8+9+9+9+4+7)/6=7	8
9	D311	White	9	7	8	10	11	9	(9+7+8+10+11)/6=8	9
10	D250	Creamy	10	10	11	8	8	11	(10+10+11+8+8+11)/6=10	10
11	D28	Black	11	11	10	11	10	11	(11+11+10+11+10+11)/6=11	11
12	D258	Reddish	12	11	12	12	12	12	(12+11+12+12+12+12)/6=12	12
13	D26	Black	13	13	13	13	13	10	(13+13+13+13+13+10)/6=13	13

Note: RWC: Relative water content; SW: Seed weight: P: Point

Figure 1

Relationship between plant height vs accessions, and moisture regime at day 7

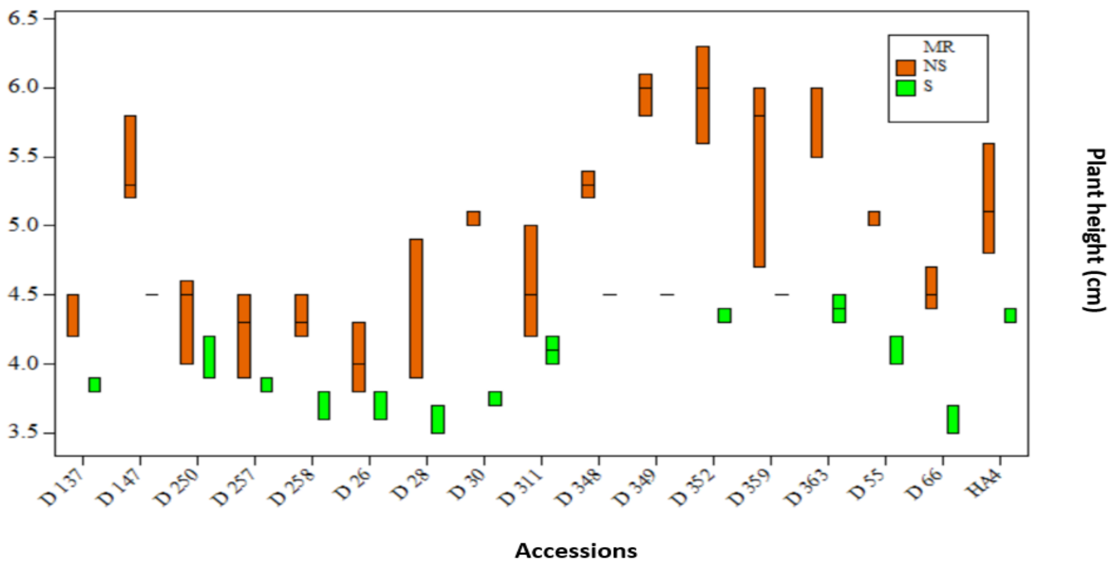


Figure 2

Relationship between root length vs accessions, and moisture regime at day 7

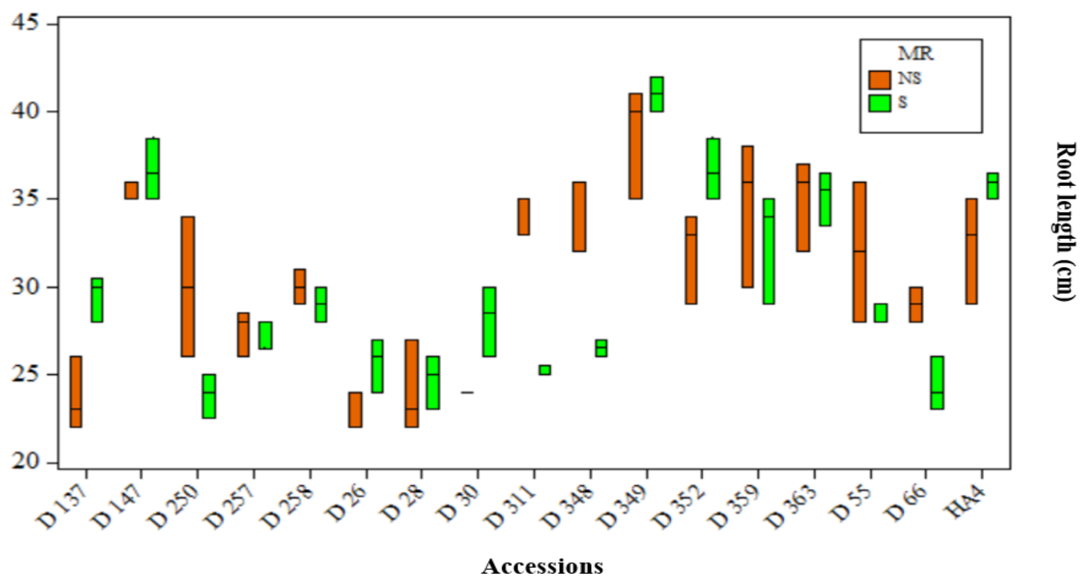


Figure 3

Relationship between shoot biomass vs accessions, and moisture regime at day 7

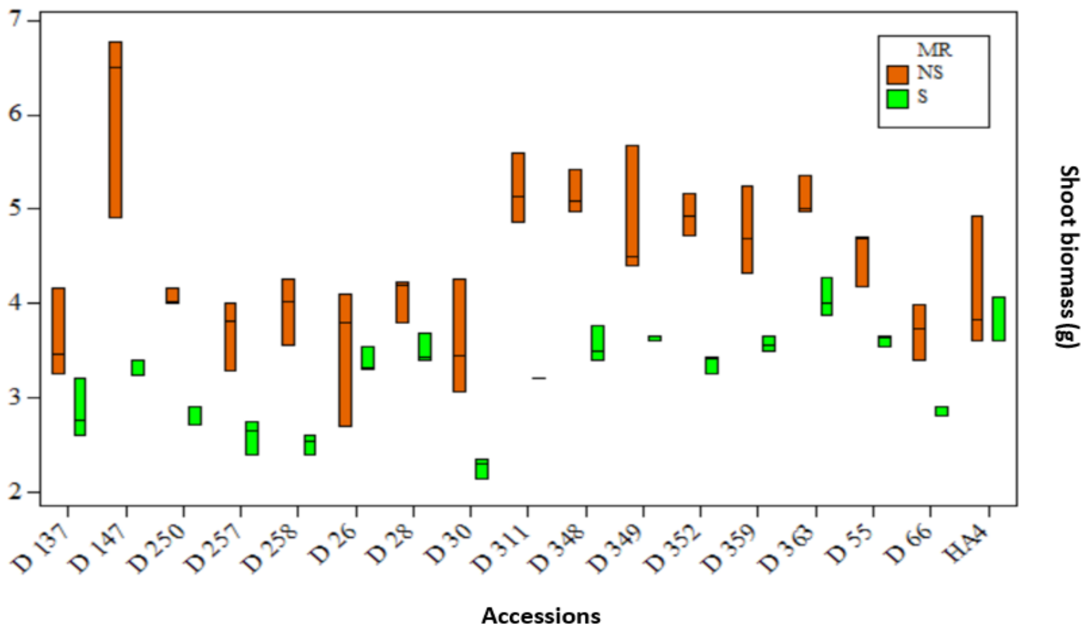


Figure 4

Relationship between root biomass vs accessions, and moisture regime at day 7

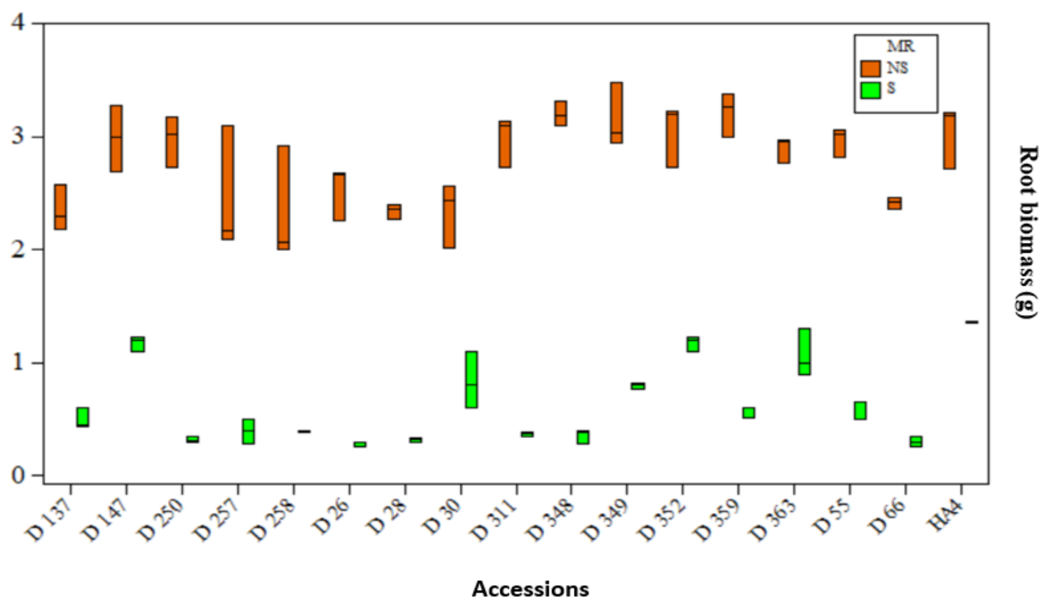
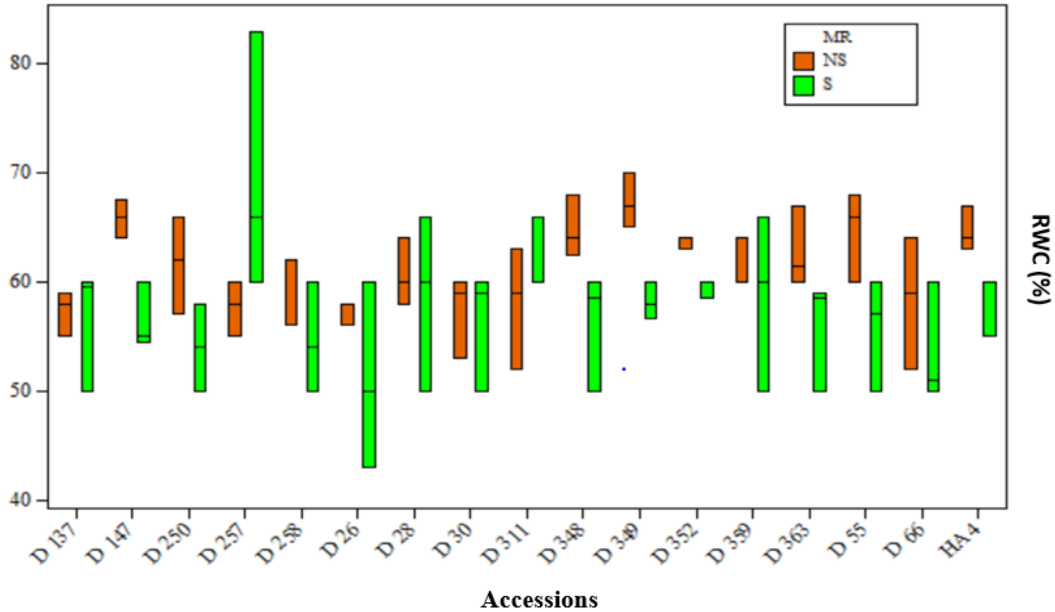


Figure 5

Relationship between RWC% vs accessions, and moisture regime at day 7



Discussion

The present study on phenotypic characteristics of Lablab accessions compared between the ST and NS seedling experimentation has proven that moisture condition is one of the crucial elements that plants require for their growth and development. According to Gavrilescu (2021), the moisture condition usually supports the proper physiological processes and functions of the plant-crops such as photosynthesis, respiration, nutrition, transportation and many others. This appropriate moisture content by plants is required right away from the beginning of their life cycle since any kind of moisture stress during the early stages of growth has an impact on proper physiological processes. According to Yang *et al.* (2021), little amount of moisture in the soil create a negative impact on the plant metabolic processes such as carbon metabolism, glycolysis, nutrient uptake, electron transport, cell division, and many others. Ultimately, moisture stress conditions to the young plants affects their stem elongation, root multiplication, and seedling growth (Bhattacharya and Bhattacharya, 2021).

A good performance of Lablab accessions in the NS experiments as well as in the early days of the TS experiments of the present study (Table 2, 3, 4 and 5) was mainly contributed by the ideal level of moisture conditions in the soil. The slow in performance among the accessions in the ST experiments especially, at the middle stages towards the end of the experiment i.e. at day 5 and 7 was basically caused by utilization of the moisture left out during withdrawal of water from the experiment after germination. Soil moisture obtained since the germination stage during the ST experiments seemed to had remained very little at day 5 and day 7 and hence providing little support to the metabolic activities of the plants. It is at this stage that, a slow growth and development of the plants was expressed through their morpho-physiological traits. However, root length was observed increasing in the ST experiments relatively compared to the NS experiments (Table 2; Figure 2) simply because, root is an important plant structure that play a great role to the absorption and maintenance of water moisture in the plants (Li *et al.*, 2021). Lablab has a potential tape root system with a network of lateral roots that support the crop during the hard times of drought stress (Akello *et* *al.*, 2023). Through its tape roots, Lablab is able to reach the moisture zone in the soil, while carrying out with nitrogen (N) fixation. Through its root systems, Lablab has a great ability to promote nutrient accumulation in root zone particularly the accumulation of Phosphorus (P) and Iron (Fe) (Senapati *et al.*, 2022). Despite a decrease in moisture content in the ST experiments, the general seedling performance of the crop had little difference compared to the NS experiments. This is because, Lablab is the DT crop able to withstand low amounts of rainfall, and high temperature of about 200 mm, and 35°C, respectively (Missanga *et al.*, 2021; Njaci *et al.*, 2023) as observed in the present study. Variations of Lablab accessions in the seedling traits (Table 2 – 4; Figure 2 - 5) was mainly due to an interaction between their genetic background and the environmental conditions. According to Maass and Chapman (2022), Lablab is the leguminous crop with a wide range of genetic diversity and physiological features. It is this great genetic diversity that Lablab is able to interact differently with environmental conditions such as moisture condition, temperature, and humidity to influence the seedling responses. Similar study by Aleme *et al.* (2023) in Lablab explains also about this interaction through some other traits and its influence in development of the crop. The Best accessions from the current study (Table 5) were also reported as the best accessions in other studies. This suggests that the selected materials could be useful resources for further evaluation in arid and semi-arid regions such as the central zone of Tanzania. HA4, D349 and D352 were as the commercial varieties in other Lablab production countries while D348 (NMD 20) and D363 (NMD 19) (experimental checks in this study) have recently been released as commercial varieties in Tanzania (Missanga *et al.*, 2023ab). Despite of being grown as a local landrace in central zone of Tanzania, D311 (Kondoa white) had promising seedling tolerance to the drought stress. Farmers' landraces are good genetic resources in terms of adoptability and nutrition, however with some challenges in pests and diseases (Missanga *et al.*, 2023a). There are some studies in other crops with similar trends found in the present study. These studies involve mainly cowpeas (Cui *et al.*, 2020; Nkomo *et al.*, 2020; Nkomo *et al.*, 2022; Manneh *et al.*, 2024; Tengey *et al.*, 2023) and a bit in Wheat (Ahmed *et al.*, 2022; Khaeim *et al.*, 2022). In the assessments for drought tolerance among various crops, several traits have been considered in the selection of the best DT accessions. Plant height, root density, and biomass were among the essential seedling traits valuable for drought tolerance screening experiments in other crops (Mahmood *et al.*, 2022). On top of that, shoot traits such as shoot biomass were reported as key seedling traits in the crop screening methods for drought tolerance in crops (Tabi *et al.*, 2020). This study has considered a wide range of parameters including all them. Photosynthetic parameters such as chlorophyl, and photosystems are also useful morpho-physiological traits in crops' screening for drought tolerance (Akello *et al.*, 2023). However many studies tend to consider then among the biochemical traits (Sharma and Sardana, 2022) as also noted in this study,

All of these seedling traits, among many others, benefit crop growth, particularly through promoting crop development, maturity and production. The DT cultivars with good seedling performance tend to have high ability to escape terminal moisture stress and therefore producing desirable yield. Lablab improved genotypes can provide 1.5 - 2.0 tones (t) of dry seeds or 2.5 - 5.0 t of green pod per ha compared to common beans (0.88 t ha^{-1}) and cowpeas (1.3-1.5 t ha^{-1}) (Nord *et al.*, 2020; Missanga *et al.*, 2023a).

Conclusion

The significant variations among the Lablab accessions in different morpho-physiological traits were identified when these accessions were evaluated for drought tolerance during the ST and NS experiments at the seedling stage. Based on the ranking method, D349, D352, D363, D359, D147, HA4, and D348 were selected as the best drought-tolerant Lablab accessions at seedling stage in arid and semi-arid conditions such as the central zone of Tanzania.

Recommendations

The best drought-tolerant Lablab accessions; D349, D352, D363, D359, D147, HA4, and D348 selected from the present study were recommended for additional drought tolerance evaluation in order to release the DT-Lablab improved varieties potential in dry condition. The future assessment proposal included biochemical analysis and RNA quantification in drought scenarios, as well as field study evaluation in arid and semi-arid environments.

Availability of data and materials

The data set associated with this paper have been kept available upon request

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