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Adaptation Studies of Mungbean (*Vigna radiate* L.) Varieties Under Irrigated Condition in the Middle Awash Rift Valley of Ethiopia: The Case of Werer Station

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Abstract: Mungbean is one of the most important pulse crops, grown from the tropical to sub-tropical areas around the world. In Ethiopia, almost half of the land mass lies with in warmer and lowland areas, with ample water resources and exploited less due to the major focus of crops production on mid to highland areas of the country receiving ample annual rainfall. In order to test the adaptability of mungbean in the lowland irrigated areas of Ethiopia, the current study was conducted at Werer research center, with the objectives to identify, select and recommend adaptable, high yielding and tolerant mungbean varieties, for irrigation production system in the lowland areas of middle awash rift valley, and at the same time assessing suitability of the area for *Vigna radiate* production. Five mungbean varieties were used in the study for two consecutive seasons (2019 and 2020). Result from the ANOVA revealed that, significant varietal differences were observed for all of the studied parameters in both seasons, except for grain filling period in the first season. The varieties Chinese, Showa-Robit and NVL-1 flowered and matured early at both growing seasons among the tested mungbean varieties. Grain yield was positively and significantly correlated with number of pods plant^{-1}, number of seeds pod^{-1} and biomass weight, and negatively correlated with phonological characters. The maximum grain yield coupled with better number of pods plant^{-1} and seeds pod^{-1} was noted for the varieties N-26 and NVL-1 in the first season and Chinese and NVL-1 in the second season. Generally, mungbean varieties tested for their adaptation under this Great Rift Valley region having warmer air condition respond well and thus the area can be characterized as suitable for production of mungbean using irrigation water.

Keywords: Great Rift Valley, Mungbean, *Vigna radiata*, Adaptation, Lowland, Irrigation, Grain Yield

1. Introduction

Mungbean (*Vigna radiate* L. Wilczek), which is introduced recently, is an annual herb of the legume family. It has green skin and is also called green bean [15]. It is sweet in flavor and cold in nature [7]. The crop matures early; special features include high yield, good nutritive value, the earliness, drought resistant features and the reasonable cost of production. It is a warm season annual grain legume and the optimum temperature range for good production is 27 to 30°C and requiring 90 to 120 days of frost-free conditions from planting to maturity depending on the variety [10].

Mungbean is one of the most important pulse crops, grown from the tropical to sub-tropical areas around the world [13], [12]. It is an important wide spreading, herbaceous and annual legume pulse crop cultivated mostly by traditional famers [2]. Mungbean has good potential for crop rotation system, for crops under drier farmland cultivation areas [5] and ability of growing on dry and irrigated conditions [16].

It is grown in several types of cultivation systems, including sole cropping, intercropping, multiple cropping and relay cropping, where it is planted after cereals using residual moisture [17]. According to [4] in Ethiopia mungbean is mostly grown by smallholder farmers under drier marginal environmental condition and the production capacity is lower than other pulse crops. Green mungbean is less used domestically, but it is a common ingredient in Chinese and Indian cuisines. It is attributed with having high nutritional value, including protein content (24 to 26%), and helps reduce cholesterol and diabetes [1, 10].

Majority of crops production in Ethiopia is concentrated in high and mid-lands receiving rainfall. Hence, production of crop plants like mungbean using irrigation under arid and semi-arid regions of the country was kept neglected for decades. Therefore, this experiment was initiated for identifying, selecting and recommending, adaptable, high yielding and tolerant mungbean varieties, under full irrigated production system in pastoral and agro-pastoral community of the Great Rift Valley region, in the middle awash rift valley, and at the same time assessing suitability of the area for production of *Vigna radiata*.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at Werer Agricultural Research Center, found in Gebiresu Zone of Afar Regional State, cover a long broad alluvial plain along the right bank of the Awash river. The elevation is at about 740 *masl* and located at 9°20’31" N latitude and 40°10’11" E longitude in the Middle Awash Rift Valley, close to the main high way linking Addis Ababa to Djibouti, and 260 km far from the capital of Ethiopia, Addis Ababa.

The climate is semi-arid with a bimodal rainfall of 533 mm annually. The mean minimum temperature is 15.2°C and the mean maximum temperature is 38°C. Mean relative humidity is lowest in June at 36% and highest in August at 58%. The area receives the average daily sunshine of 8.5 hours with an average solar radiation of 536 calories square centimeter^{-1} day^{-1} [8].

The soils are brown in color and turn to dark brown when moist. The pH of the soil is slightly alkaline and ranges from 7.5 to 8.5. The major crops grown in the area are, cotton and sugar cane with minor crops including maize, sesame, rice, wheat, pulses like chickpea and common bean, date palm, banana and vegetables in some areas around Werer Agricultural Research Center and other areas in the region.

2.2. Plant Materials and Experimental Procedures

Field evaluations of five Mungbean varieties (MH-97-1, Chinese, N-26, NVL-1 and Showa-Robit) were used in the study. The particular study was conducted during the off-seasons of 2019 and 2020 at Werer Agricultural Research Center, under fully irrigated condition. The treatments were laid in RCB design with three replications having plot size of 9.6m^2 (4m x 2.4m), accommodating 8 rows of 4m length. The spacing between rows and plants were 30cm and 5cm, respectively. Harvesting and data collection was done from six central rows and each plot was converted to net harvestable area of 7.2m^2. The plots were surface irrigated by the irrigation interval of 12-15 days that varied depending on climatic and edaphic conditions.

2.3. Measurements of Crop Phonology, Plant Growth and Yield Parameters

The study consisted of crop phonology parameters (days to 50% flowering (DF), days to physiological maturity (DM) and grain filling period (GFP)); growth parameters (plant height (PH)) and yield parameters (number of pods plant^{-1} (NPP), number of seeds pod^{-1} (NSP), biomass yield (BMY), hundred seeds weight (HSW), harvest index (HI) and grain yield (GY)). DF and DM were recorded for each variety on the plot basis by regular observation, when 50% or more of the plants flowered, as days to 50% flowering (DF) and when 90% of the pods in a plot dried, as days to physiological maturity (DM) of each plot. All crop phonology characters in the study were expressed in number of days; plant height in centimeters (cm); biomass yield and grain yield in kg ha^{-1}; and weight of hundred seeds and harvest index were expressed in gram (gm) and percentage (%), respectively.

2.4. Data Collection and Statistical Analysis

At physiological maturity, five plants from central rows were randomly selected and PH in centimeters (cm) was determined. At harvest, five sample plants were randomly selected and yield components like PPP, SPP and HSW were recorded. HI (%) was calculated as ratio of GY to total BMY*100. GY was collected from six central rows of each plot (7.2m^2) and the harvested aerial plant parts were air dried at field condition for 48hrs to determine BMY. GFP, which was defined as the number of days from 50% flowering to number of days to physiological maturity was also computed and analyzed. All measured parameters (crop phonology, growth parameters, yield and yield components) were subjected to analysis of variance (ANOVA) using PROC GLM of SAS software version 9.1 [3] and the significance of mean differences were tested by least significant difference test p≤0.05 (LSD) as stated in [9].

2.5. Correlation Coefficient (r)

A correlation coefficient is a coefficient that illustrates a quantitative measure of some type of correlation and dependence, meaning statistical relationships between two or more random variables or observed data values. Several correlation coefficient types have been widely used. Pearson’s correlation (also called Pearson’s R) is a correlation coefficient that was commonly used in linear regression. Therefore, for this particular experiment, Pearson’s correlation (r) was used to illustrate statistical relationships among the studied traits and calculated using the formula below.

$$rxy = \frac{\sum_{i=1}^{n}(Xi-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum_{i=1}^{n}(Xi-\bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i-\bar{Y})^2}}$$

3. Result and Discussions

3.1. Crop Phenology and Growth Parameters

3.1.1. Days to 50% Flowering (DF)

The effect of variety on days to 50% flowering (DF), was significant *(P≤ 0.05)* in the first season and highly significant *(P≤ 0.01)* in the second season (Table 1), in which the early days to 50% flowering were observed in variety Chinese (37.67 days) followed by Showa-Robit (38.00 days) and NVL-

1 (40.33days) on the first year (2019), whereas in the second year (2020), the variety N-26 and Chinese (36.67 days) followed by MH-97-1 (37.00 days) and Showa-Robit (39.00 days) were flowered early. Inversely, varieties MH-97-1 (43.33 days) and NVL-1 (39.67) were flowered late in both first and second year of experiments, respectively (Table 2).

3.1.2. Days to Maturity (DM)

The effect of variety on days to maturity (DM) was highly significant *(P≤ 0.01)* and significant *(P≤ 0.05)* both on first and second year, respectively (table 1). According to the result obtained, early matured variety was Chinese (67.33 days), followed by Showa-Robit (68.33 days) and MH-97-1 (71.00 days) on the first year, whereas in the second year, the variety Chinese (64.67 days) followed by MH-97-1 (65.00 days) and N-26 (66.67 days) matured early. Inversely, varieties NVL-1 (73.33 days) and Showa-Robit (68.00 days) were matured late in both first and second year of experiments, respectively (Table 2).

3.2. Plant Height (PH)

Result obtained from the studied traits of mungbean revealed that, plant height (PH) exerted highly significant *(P≤ 0.01)* varietal differences in both growing years. Significantly higher plant stature was observed on the variety Showa-Robit (42.54cm), followed by NVL-1 (30.63cm) and N-26 (29.93cm) during the first growing year, whereas in the second year, the variety Showa-Robit (47.33cm) followed by NVL-1 (46.54cm) and MH-97-1 (44.41cm) exhibited longest plant statures. Inversely, varieties Chinese (25.63 cm) and N-26 (40.07cm) were exhibited relatively shortest plant stature during the first and second growing periods, respectively (Table 2).

Similarly, [19] reported presence of significant varietal differences among the tested varieties for crop phonological characters (DF, DM), NPP, NSP, HSW and GY. [14] also reported presence of significant varietal differences among the tested varieties on GY and HSW in mungbean. In addition, [18], reported presence of highly significant varietal differences for phonological characters, growth and yield components in common bean varieties studied at the same location. [6] also reported presence of significant varietal differences for GY, DF, DM, PPP, SPP, HSW, and PH in common bean.

Table 1. *Analysis of Variance for sum of squares of mungbean traits grown under irrigation at Werer during both growing seasons (2019 and 2020).*

Characters	Year 1 (2019)						Year 2 (2020)					
	Source of Variations						Source of Variations					
	Varieties (4)¥	Replication (2)	Error (8)	Mean	CV (%)	R^2	Varieties (4)	Replication (2)	Error (8)	Mean	CV (%)	R^2
DF	16.23*	2.47	2.38	40.07	3.85	0.79	6.10**	0.60	0.60	37.80	2.05	0.84
DM	20.77**	4.07	1.57	70.53	1.77	0.88	5.90*	2.47	1.05	66.27	1.55	0.77
GFP	12.27ns	3.47	4.47	30.47	6.94	0.61	3.27*	1.07	0.82	28.47	3.18	0.70
NPP	65.41**	10.08	4.58	20.57	10.41	0.88	31.99*	9.93	6.05	30.57	8.05	0.75
NSP	1.53**	0.59	0.14	10.44	3.61	0.87	2.84**	0.72	0.26	10.81	4.75	0.86
PH (cm)	124.36***	15.40	7.34	31.55	8.59	0.90	34.89**	8.68	3.10	43.73	4.03	0.86
BMY (kg ha^{-1})	9889202**	176419	1075580	8499	12.20	0.82	2305078*	2315625	452344	7138	9.42	0.79
GY (kg ha^{-1})	147332**	353	10317	1831	5.55	0.88	64799*	159499	14252	1930	6.19	0.84
HI (%)	23.97*	0.56	3.54	22.08	8.51	0.77	19.66**	0.34	1.16	24.32	4.43	0.90
HSW (gm)	1.12**	0.04	0.15	6.08	6.37	0.79	0.96*	0.24	0.14	5.84	6.43	0.79

Key: *, **, ns indicate significance at 0.05 and 0.01 probability levels, and non-significant, respectively. ¥=figures in parenthesis refers to degrees of freedom, CV= coefficient of variation. DF=Days to flowering, DM=Days to maturity, GFP=Grain filling period, NPP=Number of pods per plant, SPP=Number of seeds per pod, PH= Plant height, BMY=Biomass yield, YLD=Yield HI=Harvest index and HSW=Hundred seed weight.

Table 2. *Combined analysis of variance for sum of squares of mungbean traits grown under irrigation at Werer during2019 and 2020 growing seasons.*

CHARACTERS	Source of Variations					
	Varieties (4)¥	Replication (2)	Year (1)	Variety*Year (4)	Error (18)	CV (%)
DF	35.87**	0.87	38.53**	53.47**	29.13	3.27
DM	64.20**	9.8	136.53**	42.47**	24.20	1.70
GFP	32.80*	8.27	30.00**	29.33*	43.07	5.25
NPP	346.62**	5.69	750.00**	42.99ns	119.39	10.07
NSP	12.60**	1.17	1.00ns	4.90**	4.71	4.82
PH (cm)	502.99**	26.02	1112.89**	133.99**	105.72	6.44
BMY (kg ha^{-1})	11689609*	1957148	13894681**	37087510**	15250328	11.77
YLD (kg ha^{-1})	233029ns	145506	72533ns	615494**	370743	7.63
HI (%)	129.82**	0.12	37.43**	44.67**	39.26	6.37
HSW (gm)	7.93**	0.46	0.43ns	0.39ns	2.41	6.15

Key: *, **, ns indicate significance at 0.05 and 0.01 probability levels, and non-significant, respectively. ¥=figures in parenthesis refers to degrees of freedom, CV= coefficient of variation. DF=Days to flowering, DM=Days to maturity, GFP= Grain filling period, PPP=Number of pods per plant, SPP=Number of seeds per pod, PH= Plant height, BMY=Biomass yield, GY= Grain Yield HI=Harvest index and HSW=Hundred seed weight.

Table 3. *Mean performances of mungbean varieties for crop phonology and growth traits.*

S/N	VARIETY	Year	DF	DM	GFP	PH (cm)
1	MH-97-1	1	43.33[a]	71.00[a]	27.67[b]	28.99[b]
		2	37.00[b]	65.00[bc]	28.00[b]	44.41[a]
2	Chinese	1	37.67[c]	67.33[b]	29.67[ab]	25.63[b]
		2	36.67[b]	64.67[c]	28.00[b]	40.29[b]
3	N-26	1	41.00[ab]	72.67[a]	31.67[a]	29.93[b]
		2	36.67[b]	66.67[ab]	30.00[a]	40.07[b]
4	NVL-1	1	40.33[bc]	73.33[a]	33.00[a]	30.63[b]
		2	39.67[a]	67.00[a]	27.33[b]	46.54[a]
5	Showa-Robit	1	38.00[c]	68.33[b]	31.67[a]	42.54[a]
		2	39.00[a]	68.00[a]	29.00[ab]	47.33[a]
GRAND MEAN		1	40.07	70.53	30.47	31.55
		2	37.8	66.27	28.47	43.73
LSD		1	2.91	2.36	3.98	5.10
		2	1.46	1.93	1.70	3.32

Key: Year1=2019, Year2=2020, DF=Days to flowering, DM=Days to maturity, GFP= Grain filling period, PH=Plant height.

3.3. Yield Components

3.3.1. Number of Pods Plant^{-1}

The productive capacity of majority of legumes is ultimately considered by the number of pods plant^{-1}. So, this makes the character one of the key factors determining the yield performance in grain legumes generally, and mungbean crop particularly.

Results obtained from the ANOVA showed that, variety had highly significant *(P≤ 0.01)* and significant *(P≤ 0.05)* influence on number of pods plant^{-1} during first and second growing periods, respectively (Table 1). Significantly, higher number of podsplant^{-1} were obtained by the variety Showa-Robit (26.00, 35.33), followed by NVL-1 (25.33, 31.80) during the first and second growing seasons, respectively (Table 4). Inversely, the lowest value of the characters was exhibited by the varieties MH-97-1 (16.73) and N-26 (17.73) on the first growing season.

3.3.2. Number of Seeds Pod^{-1}

Analysis of variance indicated that, there is presence of a highly significant *(P≤ 0.01)* difference among the varieties for this particular trait, both in first and second growing seasons. Better number of seeds pod^{-1} was obtained from the varieties Showa-Robit, followed by MH-97-1 and NVL-1 in the first growing season and MH-97-1 and NVL-1 in the second growing season. Inversely, the lowest values were observed on Chinese variety during both growing seasons (Table 4).

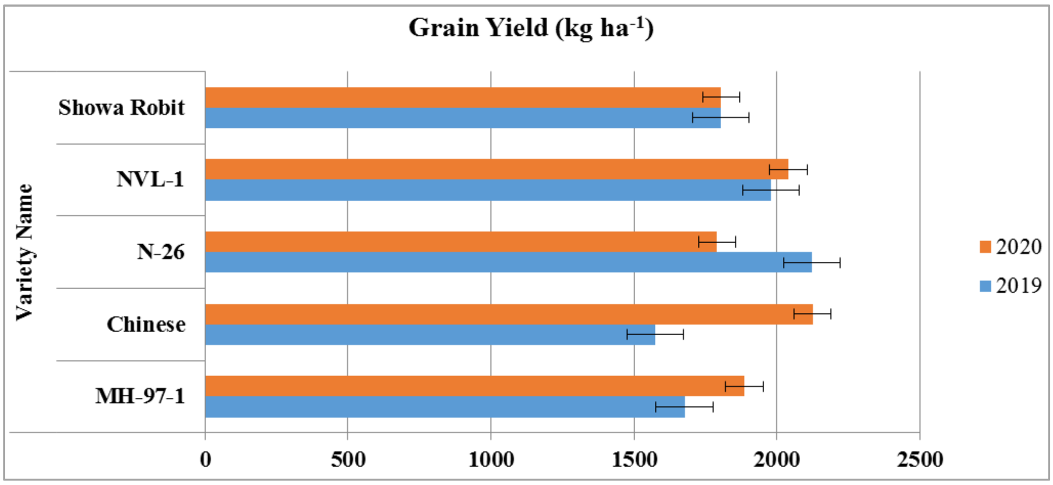

Figure 1. *Graphic illustration on mean of yield for the tested varieties of each growing season.*

Table 4. *Mean performances of mungbean varieties for Yield and Yield related components.*

S/N	VARIETY	Year	NPP	NSP	BMY (kg ha^{-1})	GY (kg ha^{-1})	HI (%)	HSW (gm)
1	MH-97-1	1	16.73[b]	10.40[b]	8472.2[bc]	1676.78[cd]	19.80[b]	5.47[b]
		2	30.67[b]	11.57[a]	7250.0[ab]	1887.04[bc]	26.06[a]	5.44[c]
2	Chinese	1	17.07[b]	9.83[b]	6194.4[d]	1575.31[d]	25.67[a]	6.82[a]
		2	27.53[b]	9.20[c]	8250.0[a]	2124.54[a]	25.84[a]	6.31[ab]
3	N-26	1	17.73[b]	10.19[b]	10750.0[a]	2121.69[a]	19.93[b]	6.48[a]
		2	27.53[b]	10.60[b]	5937.5[c]	1791.20[c]	23.63[b]	6.54[a]
4	NVL-1	1	25.33[a]	10.13[b]	9722.2[ab]	1979.31[ab]	20.40[b]	6.16[ab]
		2	31.80[ab]	11.47[ab]	7562.5[ab]	2039.35[ab]	20.11[c]	5.68[bc]

S/N	VARIETY	Year	NPP	NSP	BMY (kg ha^{-1})	GY (kg ha^{-1})	HI (%)	HSW (gm)
5	Showa-Robit	1	26.00^{a}	11.67^{a}	7354.2^{cd}	1802.89^{bc}	24.62a	5.44b
		2	35.33^{a}	11.20^{ab}	6687.5^{bc}	1805.55^{c}	25.95a	5.22c
GRAND MEAN		1	20.57	10.44	8498.61	1831.2	22.08	6.075
		2	30.57	10.8	7137.5	1929.54	24.32	5.84
LSD		1	4.03	0.71	1952.7	191.24	3.54	0.73
		2	4.63	0.97	1266.3	224.77	2.03	0.71

Key: Year1=2019, Year2=2020, NPP=Number of pods per plant, SPP=Number of seeds per pod, BMY=Biomass yield, YLD=Yield HI=Harvest index and HSW=Hundred seed weight.

3.4. Correlation of the Characters

A Pearson correlation analysis was done in order to assess the association of various agronomic characters of mungbean in this experiment. Both positive association and non-association between characters of the component crop have been observed and discussed below.

According to the result obtained from the analysis, number of pods plant^{-1} (0.27*), number of seeds pod^{-1} (0.06*) and biomass yield (0.67**) affected grain yield positively and significantly. This shows that, these factors were responsible for the production of grain yield in mungbean. This study is in line with the study by [19], reported positive and significant correlation of grain yield with NPP, NSP and HSW in mungbean. In contrast, both days to flowering (DF) and days to maturity (DM) affected grain yield negatively and the observed association was very weak and non-significant (Table 5).

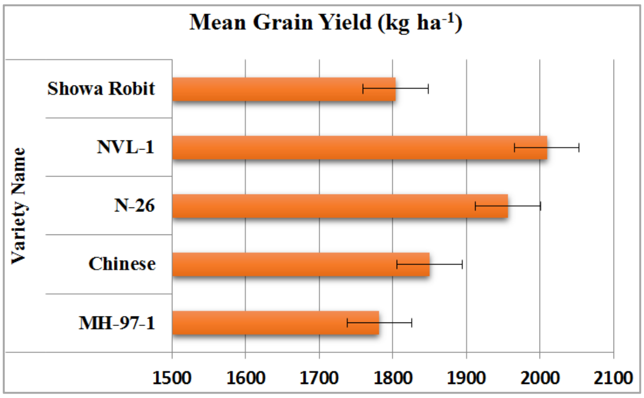

Figure 2. *Graphic illustration on mean grain yield of the tested varieties combined at both growing seasons.*

Table 5. *Correlation coefficients (r) among 10 studied traits of mungbean varieties grown under irrigation condition at Werer (2019 and 2020).*

CHARACTERS	DF	DM	GFP	NPP	NSP	PH	BMY	GY	HI
DF	1.00								
DM	0.70**	1.00							
GFP	-0.08	0.66**	1.00						
NPP	-0.41*	-0.45*	-0.19	1.00					
NSP	-0.07	-0.19	-0.20	0.48*	1.00				
PH	-0.42*	-0.57**	-0.36	0.87**	0.62**	1.00			
BMY	0.52**	0.56**	0.22	-0.29	-0.16	-0.31	1.00		
GY	-0.04	-0.03	0.01	0.27*	0.06*	0.25	0.67**	1.00	
HI	-0.74	-0.62**	-0.10**	0.35	0.02	0.30	-0.66*	0.25	1.00
HSW	-0.24	0.10	0.40*	-0.47*	-0.61	-0.55*	0.02	0.01	0.01

4. Conclusion and Recommendations

Mungbean (*Vigna radiata* L. Wilczek) is an essential short duration, self-pollinated diploid legume crop with high nutritive values and nitrogen fixing ability. It is an eco-friendly food grain leguminous crop of dry land agriculture with rich source of proteins, vitamins, and minerals. As almost half of the land mass in Ethiopia lies within warmer and lowland areas, with ample water resources and exploited less due to the major focus of crops production on other areas receiving sufficient annual rainfall, there must be extension of crops adapting and responding better in the lowland areas of the country.

From this particular study, almost all of the studied characters exhibited significant and highly significant varietal differences at both growing periods except GFP during the first (2019) growing period indicating the existence of variability among the tested varieties for the studied parameters in this experimentation.

The middle awash area, in the Great Rift Valley region of Ethiopia found to be suitable agro-ecological zone for the production of mungbean. However, additional investigations has to be conducted on other crop management packages necessary for the escalation of grain yield in mungbean grown under irrigation condition of the study area, and other areas having similar agro-ecology. It can also be noted that, extension works on these newly adapted crop varieties should be conducted to address the end producers with the varieties.

5. Contribution/Originality

This research finding contributes concrete information and attends the issues of best adaptable varieties to the specific agro-ecology (Middle Awash valley) for mungbean producers, both at small and large scale farm levels.

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