chemistry proceedings

Proceeding Paper

Evaluation of Forage Yield and Quality of Cowpea, Guar, and Mung Bean under Drought Stress Conditions †

Vida Ghotbi [1,*], Ali Mahrokh [1], Ali Mostafa Tehrani [2] and Hormoz Asadi [1]

1 Seed and Plant Improvement Institute, Agricultural Research, Education and Extension Organization (AREEO), Karaj 3135933151, Iran; ali_mahrokh229@yahoo.com (A.M.); hormoz.asadi3@gmail.com (H.A.)
2 Animal Science Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Karaj 3146618361, Iran; atehrani7m@gmail.com
* Correspondence: vghotbi@spii.ir

† Presented at the 1st International Online Conference on Agriculture—Advances in Agricultural Science and Technology, 10–25 February 2022; Available online: https://iocag2022.sciforum.net/.

Abstract: Identifying annual forage legumes suitable for summer cultivation can be a solution for forage production. Annual summer grain legumes such as cowpea, mung bean, and guar also have good potential for forage production. These summer crops would have different potential of forage yield, especially in drought conditions. Therefore, the objective of this study was to evaluate the quantitative and qualitative forage traits of these three types of summer legumes, including cowpea (Mashhad cultivar), mung bean (Parto cultivar), and guar (local cultivar of Sistan) under drought stress conditions. Methods: A split-plot experiment in a randomized complete-block design with three replications was conducted at the Seed and Plant Research Improvement Institute (SPII), Karaj, Iran for two years in 2019–2020. The study included three irrigation treatments (30, 50, and 70% soil-moisture depletion) as the main plots and the three legume species as subplots. The highest mean fresh forage yield was obtained for cowpea and mung bean (22.29 and 20.39 t ha^{-1}, respectively), while 9.37 t ha^{-1} was obtained for guar, although dry forage-yield difference between cowpea and mung bean was not significant (5.03 and 4.71 t ha^{-1}, respectively). In addition, dry forage-yield difference between 30 and 50% soil-moisture depletion was not significant (4.58 and 3.77 t ha^{-1}, respectively). The highest percent of crude protein was observed at normal irrigation for mung bean (16.97%). Furthermore, the highest levels of insoluble fiber in neutral detergent (NDF) and metabolizable energy (30.90 and 2.30, respectively) were observed for mung bean at severe stress. The highest mean forage yield was obtained for cowpea and mung bean, and irrigation after 50% soil-moisture depletion in the three legume species can be recommended.

Keywords: dry forage yield; fresh forage yield; qualitative traits; summer legumes

check for updates

Citation: Ghotbi, V.; Mahrokh, A.; Tehrani, A.M.; Asadi, H. Evaluation of Forage Yield and Quality of Cowpea, Guar, and Mung Bean under Drought Stress Conditions. *Chem. Proc.* **2022**, *10*, 62. https://doi.org/10.3390/IOCAG2022-12288

Academic Editor: Daniel Tan

Published: 15 February 2022

1. Introduction

One of the effective ways to improve resource productivity in agricultural and livestock systems is to pay attention to crops with high adaptability to environmental conditions and nutritional value. Annual summer legumes such as cowpea, mung bean, and guar are often used for human nutrition, and also have good potential for forage production. These crops could play an important role in providing part of the required forage due to higher dry-matter yield, crude protein, high ability to nitrogen fixation, rapid growth, drought tolerance, increased biodiversity, and reduced demand for chemical fertilizers and increasing the yield of cultivated crops after them. These crops are cultivated as a multipurpose plant for green pod production, vegetables, dry-seed producers, as well as forage [1].

Cowpea (*Vigna unguculata*) and Mung bean (*Vigna radiate*) are valuable crops in the sustainable agricultural system in tropical, temperate, and dry areas [2,3]. Cowpea and mung bean fodders are palatable and balanced-nutrient feeds for livestock and they can be well ensiled [2,3]. They can also be mixed with corn and sorghum [4] for higher yield and quality compared to pure culture and can be cultivated as a secondary crop after crops such as wheat and rice, due to the short growth period (growth period of 90 to 120 days for cowpea and 90–80 days for mung bean) [5,6]. Some studies have shown that drought stress has no effect on mung bean species, and it is known as a drought-tolerant plant [7].

Cluster bean or Guar (*Cyamopsis tetragonoloba*) is annual crop that is generally considered a drought-tolerant crop, and grows well in alluvial soils and sandy loam with a pH of about 7.5–8. The whole plant of guar is used as fodder for cattle and sheep. However, guar meal is a by-product of the process of separating guar gum for use in the food industry and human consumption and even poultry feed [8].

On the other hand, in most parts of the world, drought or imbalance between water supply and demand is one of the most important factors limiting agricultural production, especially in areas with arid and semiarid climates [9]. Low irrigation is an optimal strategy to cultivate crops under water scarcity, which will be accompanied by reduced yields. The main purpose of implementing low irrigation is increasing water-use efficiency, since cowpea, mung bean, and guar indicated appropriate tolerance to limited irrigation. Rao and Northub [10,11], in order to measure water use by five species of summer legumes, reported that guar, cowpea, and mung bean showed less water deficiency and used less soil water, and also indicated that soybean, pigeon pea, and guar provided the highest forage yield, while higher digestibility was observed for cowpea, mung bean, and soybean. Therefore, the purpose of this study is to compare the water productivity, forage yield potential, and forage quality of cowpea, mung bean, and guar.

2. Materials and Methods

2.1. Experimental Design

In order to evaluate and compare water productivity and forage-production potential of legume crops including cowpea (Mashhad cultivar), mung bean (Parto cultivar), and guar (local cultivar of Sistan) for summer cultivation, two experiments were conducted at the Seed and Plant Improvement Research Institute (SPII) Karaj (48°50′ E and 35°49′ N; altitude 1360 m), Iran for two years, 2019–2021. The experiments were performed in split plots in a randomized complete-block design with three replications. The main plots were different levels of soil moisture (30, 50, and 70% moisture depletion of plant available water as normal, mild, and severe water-deficit conditions, respectively) and the subplots were three legumes.

2.2. Treatments

The genotypes were planted in the first week of July in 18 m^2 plots and the distance between plants on row was 5 cm. Different irrigation treatments were applied from the stage of plant establishment. Soil moisture was checked with TDR device. In the first step, field capacity (FC) and permanent wilting point (PWP) were calculated by pressure-plate device, and afterwards, plant available water (PAW) was computed from PAW = FC − PWP [12]. The amount of irrigation was determined by the irrigation meter of each plot, and Table 1 presents the number of irrigation times and the amount of irrigation over the two years.

Table 1. The number of irrigation times and the amount of irrigation in two years.

Irrigation Treatments	Number of Irrigation Times		Cumulative Amount of Irrigation (m^3 ha^{-1})	
	2019	2020	2019	2020
Normal condition (30% moisture depletion)	9	9	9230	9000
Medium stress (50% moisture depletion)	6	6	6150	6050
Severe stress (70% moisture depletion)	5	5	5120	5000

Plants per experimental plots were harvested at 50% pod formation in order to obtain fresh and dry forage yield. In addition, forage quality traits including dry matter, ash, crude protein, neutral detergent fiber (NDF), metabolic energy (ME), and organic-matter digestibility were measured by chemical methods at the Animal Science Research Institute of Iran (ASRI) for samples of the first year of experiment.

Water productivity (WP), which is a factor that indicates the production rate of a plant with respect to the consumed water, was calculated by the following equation [13]:

$$\mathrm{WP} = \frac{fresh\ forage\ yield}{consuming\ water}\ (kg\ m^{-3})$$

2.3. Statistical Analysis

The combined analysis of variances of the split-plot design (ANOVA) and means comparisons (with the least-significant-difference (LSD) test) across the two years were performed using the MIXED procedure of SAS v 9.4 (SAS Institute Inc., Cary, NC, USA) after performing the homogeneity test.

3. Results and Discussion

3.1. Forage Yield and Agronomical Traits

The means comparisons of all traits were significantly higher in the first year. Annual variations in biomass production by cowpea, mung bean, and soybean have also been reported by Rao et al. [11] and Muir et al. [14]. This disparity was likely related to differences in growing conditions. The effect of the first water-level stress on traits showed that the mean of fresh and dry forage yield and plant height were more than the second and third stress level; however, there were no significant differences between the first and the second level of stress. The means of plant height for stress levels were 60.39, 57.17, and 52.33 cm, respectively, and the means for fresh and dry forage yields were observed as 19.28, 17.30, and 15.46 T ha^{-1}, respectively, and 4.58, 3.77, and 3.42 T ha^{-1} (Table 2).

Means of legumes indicated that in general, the mean of fresh forage yield for cowpea (22.29 T ha^{-1}) was higher than mung bean (20.39 T ha^{-1}), but the means of dry forage yield of cowpea and mung bean were not significantly different (5.03 and 4.71 T ha^{-1}, respectively). Furthermore, water productivity for cowpea and mung bean was not significantly different (3.40 and 3.15 kg m^{-3}) and higher than for guar (1.44 kg m^{-3}). Water productivity for the severe water deficit was higher than other levels of stress (Table 2). Rao and Northub [10,11], in order to measure water use by five species of summer legumes, reported that guar, cowpea, and mung bean showed less water deficiency and used less soil water, and also indicated that soybean, pigeon pea, and guar provided the highest forage yield, while higher digestibility was observed for cowpea, mung bean, and soybean.

Comparing means for interactions between the studied legumes and the years showed that the means of fresh forage yield and water productivity for cowpea was higher than other plants in first year, but there was no significant difference between the dry forage yield of cowpea and Mung bean in two years (Table 2). The interaction means of studied legumes and different levels of stress also showed that there were no significant differences between mung bean and cowpea for the second and third levels of stress for fresh and dry forage yield. The significant higher water productivity amounts were observed for mung bean and cowpea at the second and third levels of stress. Souza et al. [15] reported that an irrigation depth equivalent to 50% of the water demand in the reproductive stage led to a water-use efficiency similar to that obtained with an irrigation depth of 100%, and can be adopted in periods and regions of the state where water is a limiting factor.

Table 2. Effect of water stress on the forage-yield parameters of summer legumes in the two successive years.

Treatment	Plant Height (cm)		Fresh Yield (T ha^{-1})		Dry Yield (T ha^{-1})		Water Productivity (kg m^{-3})	
Year								
2019	61.18	a	20.00	a	4.45	a	3.04	a
2020	52.07	b	14.69	b	3.40	b	2.29	b
LSD (p < 0.05)	3.21		2.59		0.8		0.44	
Drought stress level								
Water-deficit (30%)	60.39	a	19.28	a	4.58	a	2.11	c
Water-deficit (50%)	57.17	a	17.30	b	3.77	b	2.83	b
Water-deficit (70%)	52.33	b	15.46	c	3.42	b	3.05	a
LSD (p < 0.05)	3.57		1.05		0.38		0.21	
Legumes								
Cowpea (C)	58.28	a	22.29	a	5.03	a	3.40	a
Mung bean (M)	59.50	a	20.39	b	4.71	a	3.15	a
Guar (G)	52.10	b	9.37	c	2.03	b	1.44	b
LSD (p < 0.05)	3.00		1.69		0.49		0.28	
Interactions Water Deficit × Legume								
water-deficit 30% × (C)	62.50	a	25.86	a	6.46	a	2.83	c
water-deficit 30% × (M)	62.50	a	21.85	b	5.09	b	2.40	c
water-deficit 30% × (G)	56.17	b	10.15	d	2.20	d	1.11	d
water-deficit 50% × (C)	57.67	ab	21.36	b	4.58	bc	3.50	ab
water-deficit 50% × (M)	60.00	ab	20.64	b	4.70	b	3.38	b
water-deficit 50% × (G)	53.83	b	9.89	d	2.00	d	1.62	d
water-deficit 70% × (C)	54.67	b	19.65	bc	4.04	c	3.88	a
water-deficit 70% × (M)	56.00	b	18.67	c	4.32	bc	3.68	ab
water-deficit 70% × (G)	46.33	c	8.07	d	1.92	d	1.59	d
LSD (p < 0.05)	5.19		2.92		0.86		0.48	
Interactions Year × Legume								
2019 × (C)	62.00	a	26.86	a	5.3	a	4.03	a
2019 × (M)	62.44	a	22.90	b	5.68	a	3.52	b
2019 × (G)	59.11	ab	10.24	d	2.35	c	1.57	d
2020 × (C)	54.55	c	17.72	c	4.7	a	2.77	c
2020 × (M)	56.55	bc	17.78	c	3.74	b	2.79	c
2020 × (G)	45.11	d	8.50	d	1.72	c	1.31	d
LSD (p < 0.05)	4.24		2.38		0.7		0.39	

Means in each column, followed by similar letter(s) are not significantly different at 5% probability level, using LSD's test.

3.2. Forage Quality Traits

The results of analysis of quality traits for the first year of forage samples indicated that the ranges of percentages of traits included those for dry matter from 95.35 to 95.15; for crude protein from 15.55 to 14.15%; NDF from 30.02 to 28.46; ash from 8.72 to 9.79; metabolizable energy from 2.21 to 20.18; and organic matter digestibility from 61.39 to 60.50 at three levels of stress.

The results of comparing the mean for the effect of legume type on different traits showed that the percentage of dry matter has a range from 95.29 to 95.26, crude protein a range from 15.39 to 14.23%, insoluble fiber in acidic detergent with a range from 29.63 to 12.29, ash ranged from 9.01 to 9.51, metabolizable energy ranged from 2.22 to 2.17, and organic matter digestibility ranged from 61.69 to 60.20, and there was no significant difference between the types of legumes studied in terms of characteristics (Table 3).

Table 3. Effect of water stress on forage-quality parameters of three summer legumes.

Treatment	Dry Matter		Crude Protein		NDF		Ash		ME (Mcal/kg)		Organic Matter Digestibility	
Drought stress level												
water-deficit (30%)	95.35	a	15.48	a	29.83	a	9.79	a	2.18	a	60.56	a
water-deficit (50%)	95.35	a	15.55	a	28.46	a	8.72	a	2.21	a	61.39	a
water-deficit (70%)	95.15	a	14.15	a	30.02	a	9.52	a	2.18	a	60.50	a
LSD	0.24		1.63		2.11		1.87		0.07		2.03	
Legumes												
Cowpea (C)	95.29	a	15.39	a	29.56	a	9.01	a	2.17	a	60.20	a
Mung bean (M)	95.26	a	14.56	a	29.63	a	9.51	a	2.18	a	60.54	a
Guar (G)	95.29	a	14.23	a	29.12	a	9.51	a	2.22	a	61.69	a
LSD	0.21		1.53		2.48		0.96		0.17		4.66	
Interactions Water Deficit × Legume												
water-deficit 30% × (C)	95.44	a	15.68	abc	30.17	a	10.17	a	2.13	a	59.01	a
water-deficit 30% × (M)	95.37	ab	16.97	a	29.28	a	9.50	a	2.16	a	59.76	a
water-deficit 30% × (G)	95.23	ab	13.80	cd	30.05	a	9.70	a	2.27	a	62.90	a
water-deficit 50% × (C)	95.26	ab	13.98	bcd	28.63	a	7.05	b	2.29	a	63.49	a
water-deficit 50% × (M)	95.37	ab	14.45	abcd	28.70	a	10.08	a	2.09	a	58.16	a
water-deficit 50% × (G)	95.41	a	15.22	abc	28.03	a	9.03	a	2.26	a	62.51	a
water-deficit 70% × (C)	95.17	ab	16.51	ab	29.87	a	9.82	a	2.10	a	58.12	a
water-deficit 70% × (M)	95.04	b	12.27	d	30.90	a	8.95	a	2.30	a	63.71	a
water-deficit 70% × (G)	95.23	ab	13.69	cd	29.28	a	9.80	a	2.15	a	59.68	a
LSD	0.36		2.66		4.29		1.69		0.31		8.06	

Means in each column, followed by similar letter(s) are not significantly different at 5% probability level, using LSD's test.

The interaction of the studied legumes and different levels of stress also showed that although in general the average percentage of dry matter for cowpea (99.44%) was higher than other crops at normal stress levels, no significant difference was observed between other levels and plants. The highest amount of crude protein was observed at normal stress level for mung bean (16.97%). The highest amounts of insoluble fiber in neutral detergent (NDF) and metabolizable energy (30.90 and 2.30, respectively) were observed for mung bean at severe stress levels, and in general no significant differences were observed among legumes and stress levels. The highest digestibility of organic matter was obtained for cowpea at severe stress levels, although no significant difference was observed for this trait between stress levels and legume type (Table 3).

The study revealed that all the forage-quality traits considered did not vary significantly across water regimes and summer legume types. This confirmed that the nutritional quality of legume types was not affected by irrigation type and water regime. This confirms the drought tolerance of the studied legume and the ability to retain nutritional composition under drought, as was mentioned by Kanda et al. [16]. This makes it an important crop for addressing food and nutritional security in water-scarce environments.

4. Conclusions

The study revealed that the highest mean fresh forage yield was obtained for cowpea and then for mung bean, although dry forage-yield difference between cowpea and mung bean was not significant. Furthermore, dry forage-yield difference between two irrigation levels (normal and mild stress) was not significant. The highest percent of crude protein was observed at normal irrigation levels for mung bean. Forage-quality traits were not affected by type of summer legume types and water-stress levels. Finally, based on the results, for saving irrigation water in areas where water resources are limited, irrigation of 50% of soil-water depletion in the three legume species can be recommended.

Author Contributions: Conceptualization, V.G.; data curation, V.G; investigation, V.G., A.M. and A.M.T.; methodology, V.G. and H.A.; project administration V.G.; resources, V.G.; supervision, V.G.; writing—original draft, V.G.; writing—review and editing V.G. and A.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are available on request.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Stoilova, T.; Pereira, G. Assessment of the genetic diversity in a germplasm collection of cowpea (*Vigna unguiculata* (L.) Walp.) using morphological traits. *Afr. J. Agric. Res.* **2013**, *8*, 208–215. [CrossRef]
2. Khatik, K.L.; Vaishnava, C.S.; Gupta, A.N.D.L. Nutritional evaluation of green gram (*Vigna radiata* L.) straw in sheep and goats. *Indian J. Small Rumin.* **2007**, *13*, 196–198.
3. Singh, B.B.; Ajeigbe, H.A.; Tarawali, S.A.; Fernandez-Rivera, S.; Musa, A. Improving the production and utilization of cowpea as food and fodder. *Field Crops Res.* **2003**, *84*, 169–177. [CrossRef]
4. Ahmad, U.H.A.; Ahmad, R.; Mahmood, N.; Tanveer, A. Performance of forage sorghum intercropped with forage legumes under different planting patterns. *Pak. J. Bot.* **2007**, *39*, 431–439.
5. Ashour, N.I.; Behairy, G.T.; Abd EL-Lateef, E.M.; Selim, M.M. A preliminary study on the potentiality of intercropping of mung bean (*Vigna radiata* Roxb.) with dwarf grain sorghum (*Sorghum bicolor* Moench) in Egypt. *Bull. Natl. Res. Cent.* **1991**, *16*, 53.
6. Dorrenbos, J.; Kassam, A.H. Yeild response to water. In *FAO Irrigation and Drainage Paper*; No. 33; FAO: Rome, Italy, 1979.
7. Lambrides, C.J.; Godwin, I.D. Mung bean. In *Genome Mapping and Molecular Breeding in Plants*; Chittarajan, K., Ed.; Springer: Berlin/Heidelberg, Germany, 2007; Volume 3, pp. 69–90.
8. Lee, J.T.; Bailey, C.A.; Cartwright, A.L. Guar meal germ and hull fractions differently affect growth performance and intestinal viscosity of broiler chickens. *Poult. Sci.* **2003**, *82*, 1589–1595. [CrossRef] [PubMed]
9. Shahram, A.; Daneshi, N. Appropriate level of irrigation water needed in agriculture, White beans. In Proceedings of the Ninth Congress of Soil Science, Tehran, Iran, 28–31 August 2005. (In Persian).
10. Rao, S.C.; Northup, B.K. Capabilities of four novel warm-season legumes in the southern Great Plains: Biomass and forage quality. *Crop Sci.* **2009**, *49*, 1096–1102. [CrossRef]
11. Rao, S.C.; Northup, B.K. Water Use by Five Warm-Season Legumes in the Southern Great Plains. *Crop Sci.* **2009**, *49*, 2317–2324. [CrossRef]
12. Kirkham, M. Field capacity, wilting point, available water, and the non-limiting water range. In *Principles of Soil and Plant Water Relations*; Academic Press: Burlington, NJ, USA, 2005; pp. 101–115. [CrossRef]
13. Cook, S.; Gichuki, F.; Turral, H. Water productivity: Estimation at plot, farm and basin scale. In *People and Agro-Ecosystems Research for Development Challenge*; CIAT: Cali, Colombia, 2006; p. 144.
14. Muir, J.P. Hand-plucked forage yield and quality and seed production from annual and short-lived perennial warm season legumes fertilized with composted manure. *Crop Sci.* **2002**, *42*, 897–904. [CrossRef]
15. Souza, P.J.; Ramos, T.F.; Fiel, L.D.; Farias VD, D.S.; Sousa DD, P.; Nunes, H.G. Yield and water use efficiency of cowpea under water deficit. *Rev. Bras. Eng. Agríc. Ambient.* **2019**, *23*, 119–125. [CrossRef]
16. Kanda, E.K.; Senzanje, A.; Mabhaudhi, T.; Mubanga, C.S. Nutritional yield and nutritional water productivity of cowpea (*Vigna unguiculata* L. Walp) under varying irrigation water regimes. *Water SA* **2020**, *46*, 410–418. [CrossRef]