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Evaluation of forage yield and quality of cowpea, guar and mung bean under drought stress conditions†

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Abstract:

Background: 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.

Aim: 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 in 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.

Results: 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). Also, dry forage yield difference between two 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%). As well, 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.

Brief conclusion: 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

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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; 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, increase biodiversity, and reduce demand for chemical fertilizers and increasing the yield of cultivated crops after them. These crops are cultivated as a multi-purpose plant for green pod production, vegetable, dry seed producer, as well as forage [19].

Cowpea (*Vigna unguculata*) and Mung bean (*Vigna radiate*) are valuable crops in the sustainable agricultural system in tropical, temperate and dry areas [6, 17]. Cowpea and mung bean fodders are palatable and balanced nutrients feed for livestock and they can be well ensiled [6, 17]. They can also be mixed with corn and sorghum [1] 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 90 to 120 days for cowpea and 90-80 days for mung bean) [2, 4]. Some studies have shown that drought stress has no effect on mung bean species and is known as a drought tolerant plant [8].

Cluster bean or Guar (*Cyamopsis tetragonoloba*) is annual crop which generally is considered as a drought tolerant crop and grow 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 food industry and human consumption and even poultry feed [9].

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 semi-arid climates [16]. 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 tolerant to limited irrigation. Rao and Northub (2009a, b) [13, 14] in order to measure water use by 5 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 in 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 sever 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 m2 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 [7]. 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 during two years.

Plants per experimental plots were harvested at 50% pod formation in order to obtain fresh and dry forage yield. Also 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 in 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 [3].

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

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, USA) after performing the homogeneity test.

Tabale 1. The number of irrigation times and the amount of irrigationin two years.

Irrigation treatments	Number of irrigation times		The 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

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 also have been reported by Rao *et al*. and Muir *et al*. [15, 11]. 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 19.28, 17.30 and 15.46 Tha-1, respectively and 4.58, 3.77 and 3.42 Tha-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), 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 significant difference (3.40 and 3.15 kg m-3) and higher than from guar (1.44 kg m-3). Water productivity for the severe water deficit was higher than other level stress (table 2). Rao and Northub (2009a, b) in order to measure water use by 5 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 is 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 second and third level of stress for fresh and dry forage yield. The significant higher water productivity amounts were observed for mung bean and cowpea at second and third level of stress. Souza *et al* [18] reported Irrigation depth equivalent to 50% of the water demand in the reproductive stage led to a water use efficiency similar to that obtained with irrigation depth of 100% and can be adopted in period and regions of the state where water is a limiting factor.

3.2. *Forage quality traits*

The results of analysis of quality traits for the first year of forage samples indicated that the range of percentages of traits included 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 ranged from 2.21 to 20.18 and organic matter digestibility ranged from 61.39 to 60.50 at three level of stress.

The results of comparing the mean for the effect of legume type on different traits show 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

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

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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 is no significant difference between the types of legumes studied in terms of characteristics (Table 3).

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 level but 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 in severe stress level, although no significant difference was observed for this trait between stress levels and legume type (Table 3).

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

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

The study revealed that all the forage quality traits considered did not vary significantly across water regimes and summer legume types. This confirmed the nutritional quality of legume types were not affected by irrigation type and water regime. This confirms the drought tolerance of the studied legume and ability to retain nutritional composition under drought as was mentioned by kanda *et al*. [5]. 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. Also, 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 level for mung bean. Forage quality traits were not affected by type of summer legume types and water stress levels. Finally, the based on the results, for saving irrigation water in area where water resource is limitation, irrigation 50 % of soil water depletion in the three legume species can be recommended.

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Vida Ghotbi: Conceptualization; data curation; investigation; methodology; project administration; resources; supervision; writing-original draft; writing-review and editing.

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