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Yield, Water Use Efficiency and Economics of Pulses as Influenced by Irrigation Levels

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Authors' contributions

This work was carried out in collaboration between both authors. Author KHS designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author PSF managed the analyses of the study and literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted on a sandy loam soil at college of Agriculture V. C. Farm Mandya, UAS Bengaluru in *kharif* 2016 to study the effect of irrigation levels on productivity of pulses in southern dry zone of Karnataka for achieving optimum irrigation schedule, higher yield and water use efficiency. The experiment was laid out in Split-plot Design with four levels of irrigation as main plot *viz.,* irrigation at 60, 80, 100 per cent CPE (cumulative pan evaporation) and irrigation as per recommended irrigation practices in Southern Dry Zone of Karnataka. The pulses grown in Sub-plots were Greengram, Blackgram and Fieldbean. Analysis was done for crop equivalent yield. The results revealed that, significantly higher greengram equivalent yield was with irrigation at 80% CPE (1710 kg ha^{-1}) as compared to irrigation at 60% CPE and recommended practice (1427 and 1502 kg ha^{-1}, respectively) but was on par with irrigation at 100% CPE (1619 kg ha^{-1}). The water use efficiency was significantly higher with irrigation at 80% CPE (44.01 kg ha-cm^{-1}) as compared to rest of the irrigation levels (28.78, 39.14 to 39.15 kg ha-cm^{-1}). The treatment combination of irrigation at 80 per cent CPE and blackgram recorded significantly higher greengram equivalent yield of 2201 kg ha^{-1} and water use efficiency (61.80 kg ha-cm^{-1}) as

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compared to rest of the combinations. The highest B: C ratio was recorded in irrigation at 80% CPE (3.63) while the lowest with recommended practices (2.96). Hence scheduling irrigation at 80 per cent CPE in pulses enhances yield, water use efficiency and profit in Southern Dry Zone of Karnataka.

Keywords: Equivalent yield; irrigation levels; pulses; water use efficiency (W.U.E).

1. INTRODUCTION

Pulses occupy a very significant place in Indian farming as they are the source of food, fodder and feed. They have ability to fix atmospheric nitrogen and play a very important role in sustaining soil productivity. Pulses are grown all over India and protein requirement of human being for growth and development is mostly met through pulses. Protein content in pulses ranges from 21-26 per cent, carbohydrates around 60 per cent and also a good source of vitamins like thiamin, riboflavin, niacin and ascorbic acid.

More than 85 per cent area under pulses depends on rainfall, while water is life of any crop [1]. The area and production growth of pulses is slow due to low productivity of 411 kg ha^{-1} during 1950-51 and 688 kg ha^{-1} during 2010-11 over six decades; however the area under pulses 19.03 million ha during 1950-51 increased to 26.68 million ha only, as compared to food grain production [1].

In view of rapid increase in population and day by day decrease in water resources and to fulfill the increasing pulse demand and decreasing pulse production; sustainable water management practices and estimation of water requirement will help to increase productivity of pulses, water productivity, water use efficiency and area of pulses under irrigation. Improving water use efficiency in agriculture will require an increase in crop water productivity i.e., an increase in marketable crop yield per unit of water used by plant and reduction in water losses from the crop root zone. Among the sustainable water management practices, scheduling irrigation based on evaporation is one of the best methods in semi arid condition where annual rainfall is low.

Crop water requirement is the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil moisture maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield [2]. The assessment of water needs of the crop based on day to day weather parameters seems to be more rational than any other method [3]. In agricultural fields, large spatial variations in soil water content are associated with soil heterogeneities such as precipitation level, land cover, topography, evapotranspiration etc. [4]. Detailed georeferenced maps would be useful to manage soil moisture levels according to soil variability to assess irrigation requirements and optimal plant nutrient managements in the field [5]. Scientific irrigation scheduling should go with an understanding of soil-water-plant-atmosphere continuum. Irrigation water economy can be aimed through appropriate irrigation schedules and meteorological approach based on pan evaporation is one of the simplest, reliable, economical and least time consuming methods [6]. Keeping this in view, the present investigation "Yield, Water Use Efficiency and Economics of Pulses as Influenced by Irrigation Levels in Southern Dry Zone of Karnataka**"** was taken up during *kharif* 2016 at college of Agriculture, Vishweshwaraiah Canal Farm. Farm, Mandya with the following objectives:

- To know the effect of irrigation levels on yield of pulses.
- To know the water use efficiency as influenced by irrigation levels in pulses.
- To work out the economics of irrigation levels in pulses.

2. MATERIALS AND METHODS

A field experiment was conducted during kharif season of 2016 at Collage of Agriculture, Vishweshwaraiah Canal Farm, Mandya (Karnataka) to study the performance of pulses with irrigation levels in southern dry zone of Karnataka. The experiment was laid out in split plot design with four irrigation levels *viz.,* irrigation at 60% (I_1), 80% (I_2), 100 % (I_3) of cumulative pan evaporation (CPE) and recommended irrigation practice in southern dry zone of Karnataka (I_4) as main plot and three pulses *viz.,* P_1: greengram (KKM-3), P_2:

blackgram (Rashmi) and P_3: fieldbean (HA-4) as sub plot with three replications. The soil of experimental site is red sandy loam with neutral soil pH (7.6), organic carbon content was medium (0.66 percent) with an electrical conductivity (EC) of 0.18 dSm^{-1}, medium in available nitrogen (275.96 kg/ha), phosphorus (30.77 kg/ha) and potassium (201.26 kg/ ha). Detail about the soil analysis methods given in Table. 1. The pulses were planted on 16 July 2010 with common row spacing of 30 and 10 cm between plants. Equal quantity of farm yard manure at the rate of 5 t/ha was applied to each plot three weeks prior to planting. The recommended doses of 25 kg of nitrogen, 50 kg P_2O_5 and 25 kg K_2O per ha were applied uniformly as basal dose at the time of planting in the form of urea, single super phosphate and muriate of potash, respectively. One general irrigation at 5 cm depth was given to all plots after sowing to ensure uniform germination and crop establishment and counted the applied water through water meter. The required quantity of water per plot based on 60%, 80% and 100% cumulative pan evaporation was calculated by using USWB open pan evaporimeter. For farmer practice water was applied @ 5 cm depth. For measuring the water to be applied for each treatments water meter was used. Measured quantity of water (liter $plot^{-1}$) was applied through surface irrigation at an interval of 8 days.

The yield was converted to greengram equivalent yield of blackgram and fieldbean and statistically analysed using Fisher's method of analysis of variance technique as given by Panse and Sukhatme [7]. Analysis of water use efficiency was done for greengram equivalent yield of blackgram and fieldbean.

3. RESULTS AND DISCUSSION

3.1 Greengram Equivalent Yield

The data recorded on grain yield of greengram, blackgram and fieldbean (Table 2) as influenced by irrigation levels was converted in to greengram equivalent yield and presented in Table 3. Irrigation at 80 per cent CPE resulted in significantly higher greengram equivalent yield 1710 kg ha^{-1}, and which was 13.84 per cent higher than the yields obtained with recommended irrigation practice (1502 kg ha^{-1}) respectively, but it was on par with Irrigation at 100 per cent CPE (1619 kg ha^{-1}). However, the lowest yield was recorded with irrigation at 60 per cent CPE (1427 kg ha^{-1}).

The treatment combinations of irrigation levels and pulses showed significant difference in greengram equivalent yield. Scheduling irrigation at 80 per cent CPE with blackgram recorded the highest greengram equivalent yield (I_2P_2: 2201 kg ha^{-1}) followed by (I_3P_2: 2084 kg ha^{-1}) as compared to all other combinations.

Irrigation scheduling at 0.8 IW/CPE ratio significantly increased the seed yield of chick pea (1156 kg ha^{-1}) respectively, as compared to irrigation schedules IW/CPE ratio 1.0, 0.6 and 0.4 [11]. These higher grain yield and yield parameters in irrigation level at 80 per cent CPE might be attributed to its key role in root development by mechanical resistance leads to greater nutrient uptake and higher transpiration resulted in more photosynthesis [12].

3.2 Total Water Used (mm Ha^{-1})

Total water used by different treatment is presented in Table 3. The lowest quantity of water was used by treatment 60 per cent CPE (360.66 mm ha^{-1}) which saved 37.05 per cent of water than recommended irrigation practice (572.94 mm ha^{-1}), 14.05 per cent than 100 per cent CPE (419.62 mm ha^{-1}) and 7.55 per cent than 80 per cent CPE (390.14 mm ha^{-1}), respectively. Irrigation levels at 80 percent CPE and 100 per cent CPE were saved 31.90 and 26.76 per cent water, respectively, over recommended irrigation level.

Total water used by all pulses (greengram, blackgram and fieldbean) were same (435.84 mm ha^{-1}).

Among treatment combinations, irrigation at 60 per cent CPE in all pulses (greengrm, blackgram and fieldbean), used lower amount of water (360.66 mm ha^{-1}) and recommended practice it was higher (572.94 mm ha^{-1}).

3.2 Water Use Efficiency

Water use efficiency of pulses (greengram, blackgram and fieldbean) was calculated for greengram equivalent yield and presented in Table 3. The trend of water use efficiency was exactly reverse to that of trend observed in grain yield except, irrigation at 80 per cent CPE. Maximum water use efficiency was observed in treatments receiving less water except, irrigation at 80 per cent CPE. Scheduling irrigation at 80 per cent CPE resulted in significantly higher water use efficiency (44.01 kg ha-cm^{-1}) as

compared to other irrigation levels. Irrigation levels 60 per cent and 100 per cent CPE recorded significantly higher water use efficiency (39.14 and 39.15 kg ha-cm^{-1}, respectively) over farmer's practice (28.78 kg ha-cm^{-1}), but were at par with each other.

The treatment combinations of irrigation levels and pulses showed significant difference in water use efficiency. Treatment combination of blackgram with irrigation level at 80 per cent CPE recorded significantly higher water use efficiency (I_2P_2: 61.80 kg ha-cm^{-1}) followed by blackgram with 100 per cent CPE (I_3P_2: 55.03 kg ha-cm^{-1}) and blackgram with 60 per cent CPE (I_1P_2: 54.72 kg ha-cm^{-1}) than other combinations. However, the lowest water use efficiency recorded with recommended irrigation level with greengram combination (I_4P_1: 17.66 kg ha-cm^{-1}).

Water use efficiency of greengram was significantly higher in irrigation schedule IW/CPE 0.8 (49.41 kg ha-mm^{-1}) over 0.6 and 1.0 IW/CPE (49.12 and 39.24 kg ha-mm^{-1}, respectively), which were significantly better than irrigation at 10 days interval (38.99 kg ha-mm^{-1}) [13]. These results might be due to the fact that under increased quantity of water applied resulted in high moisture regimes and more moisture is used for evaporation than production as the availability of water was more than the crop irrigated with less water [13].

3.4 Economics and Benefit: Cost Ratio

3.4.1 Cost of cultivation

Economics of pulses (greengram, blackgram and fieldbean) was calculated for greengram equivalent yield is presented in Table 4. The cost of cultivation was varying among the treatments. It was increased with increasing irrigation levels. The lowest cost of cultivation recorded with irrigation at 60 per cent CPE (23769 Rs ha^{-1}), followed by 80 per cent CPE (24069 Rs ha^{-1}) and 100 per cent CPE (24369 Rs ha^{-1}). The highest cost of cultivation was recorded in farmer's practice (25869 Rs ha^{-1}). Among the pulses fieldbean recorded higher cost of cultivation (26769 Rs ha^{-1}) than greengram (23019 Rs ha^{-1}) and blackgram (23769 Rs ha^{-1}).

Among the treatment combinations, irrigation scheduled with recommended irrigation practice with fieldbean recorded the highest cost of cultivation (28119 Rs ha^{-1}) than all other treatment combinations.

Table 1. Chemical properties of the soil at the experimental site

pH (1:2.5)	7.6	Neutral	Potentiometric method [8]
EC (1:2.5) (dSm^{-1})	0.18	Low	Conductometric method [8]
Organic carbon (%)	0.66	Medium	Wet oxidation method [9]
Available N (kg ha^{-1})	276.00	Low	Alkaline potassium permanganate method [10]
Available P_2O_5 (kg ha^{-1})	30.80	medium	Brays extract [8]
Available K_2O (kg ha^{-1})	201.30	medium	Flame photometry [8]

Table 2. Grain yield (kg ha^{-1}) of greengram, blackgram and fieldbean is influenced by irrigation levels

Treatments	Greengram	Blackgram	Fieldbean
I_1	**770**	**1036**	**1176**
I_2	**956**	**1222**	**1332**
I_3	**900**	**1161**	**1272**
I_4	**824**	**1066**	**1222**

I1: Irrigation at 60% CPE, I2: Irrigation at 80% CPE, I3: Irrigation at 100% CPE, I4: Irrigation as per recommended practice in southern dry zone of Karnataka

Table 3. Greengram equivalent yield (Kg ha^{-1}) of blackgram and fieldbean and water use efficiency (Kg ha-cm^{-1}) as influenced by irrigation levels

	Green gram equivalent yield (Kg ha^{-1})				Total water used (mm)				WUE (Kg ha-cm^{-1})			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
I_1	770	1826	1685	**1427**	360.66	360.66	360.66	**360.66**	23.09	54.72	39.59	**39.14**
I_2	956	2201	1974	**1710**	390.14	390.14	390.14	**390.14**	26.85	61.80	43.38	**44.01**
I_3	900	2084	1872	**1619**	419.62	419.62	419.62	**419.62**	23.79	55.03	38.63	**39.15**
I_4	824	1907	1775	**1502**	572.94	572.94	572.94	**572.94**	17.66	40.87	27.83	**28.78**
Mean	**863**	**2004**	**1826**		**435.84**	**435.84**	**435.84**		**22.85**	**53.10**	**37.36**	
	S.Em±		**CD @ 5%**						**S.Em±**		**CD @ 5%**	
Irrigation levels	**52.44**		**180.42**						**1.34**		**4.60**	
Interaction	**13.71**		**40.97**						**0.32**		**0.97**	

Table 4. Economics of greengram equivalent yield of blackgram and fieldbean as influenced by irrigation levels

	Cost of cultivation (Rs ha^{-1})				Gross returns (Rs ha^{-1})				Net returns (Rs ha^{-1})				B:C ratio			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
I_1	22269	23019	26019	**23769**	43042	102054	73464	**72853**	20773	79035	47445	**49084**	1.93	4.43	2.82	**3.06**
I_2	22569	23319	26319	**24069**	53361	122930	85920	**87404**	30792	99611	59600	**63334**	2.36	5.27	3.26	**3.63**
I_3	22869	23619	26619	**24369**	50245	116383	81529	**82719**	27376	92764	54909	**58350**	2.20	4.93	3.06	**3.40**
I_4	24369	25119	28119	**25859**	46023	106754	77313	**76697**	21654	81635	49194	**50827**	1.89	4.25	2.75	**2.96**
Mean	**23019**	**23769**	**26769**		**48168**	**112030**	**7956**		**25148**	**88261**	**52787**		**2.10**	**4.72**	**2.98**	

I1: Irrigation at 60% CPE, I2: Irrigation at 80% CPE
I3: Irrigation at 100% CPE I4: Irrigation as per recommended practice in southern dry zone of Karnataka
P1: Greengram, P2: Blackgram, P3: Fieldbean

3.4.2 Gross and net return

Irrigation with 80 per cent CPE recorded higher gross returns and net returns (87404 and 63335 Rs ha^{-1}, respectively) followed by irrigation with 100 per cent CPE (82719 and 58350 Rs ha^{-1}, respectively), recommended practice (76697 and 50827 Rs ha^{-1}, respectively) and irrigation with 60 per cent CPE (72853 and 49084 Rs ha^{-1}, respectively) with respect to greengram equivalent yield.

Among the treatment combinations, irrigation level at 80 per cent CPE with blackgram recorded higher gross returns and net returns (122930 and 99611 Rs ha^{-1}, respectively) followed by irrigation level at 100 per cent CPE with blackgram (116383 and 92764 Rs ha^{-1}, respectively) than the other treatment combinations.

3.4.3 Benefit: cost ratio

Irrigation with 80 per cent CPE was recorded higher Benefit:Cost ratio (3.63) followed by irrigation with 100 per cent CPE (3.40) and irrigation with 60 per cent CPE (3.06). While, the lowest Benefit:Cost ratio was recorded with farmer's practice with respect to greengram equivalent yield.

Among treatment combination, irrigation level at 80 per cent CPE with blackgram recorded higher Benefit:Cost ratio (5.27) followed by irrigation level at 100 per cent CPE with blackgram (4.93) than the other treatment combinations. Benefit:Cost ratio of freanchbean was significantly higher with irrigation regime IW/CPE 0.75 as compared 1.0, 0.50 and 0.25 [14].

4. CONCLUSION

As a concluding remark, the presented data showed that lower or higher soil moisture levels resulted in lower yield and water use efficiency of the pulses. Application of irrigation quantity 20 per cent less or equal to the evapotranspiration resulted in higher yield and water use efficiency of pulses in dry zone as compared to both low and high irrigation water. Adoption of irrigation at 80 per cent CPE with pulses can produce 12.16 per cent higher greengram equivalent yield with a saving of 37.05 per cent water and 1.5 times more water use efficiency as compared to recommended irrigation practice (5cm). Hence this would benefit the farmer with 24.60 per cent more net income than recommended irrigation practice.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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