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Performance and impact of supplemental irrigation to rainfed Pigeonpea through Raingun

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ABSTRACT

Background: *In India, Pigeonpea is the second most important pulse crop and is predominantly grown under rainfed conditions.In peninsular India, particularly to Andhra Pradesh viz., Ananthapuramu district where long-duration varieties predominate experience the terminal drought during the reproductive period is the major yield-limiting factor. Inthe long duration traditional pigeon pea varieties and terminal drought coexist with the crop critical stages (Flower bud initiation, flowering, pod maturing) in rainfed areas of Andhra Pradesh are the prime impediment for dwindled productivity. Thestate administration has initiated to combat the groundnut and sole pigeonpea crop by providing lifesaving supplemental irrigation through rain gun technology though it is uncommon for wide-spaced crops viz., pigeonpea and castor. Bountiful research work was taken up by the various R&D organizations in point to supplemental irrigation and recommended for the doubling of crop productivity. however supplemental irrigation through raingun was not reposited and there was a dire need to address the issue in a short while.*

Methods: *In this context to bring about a new awakening an attempt at Agricultural Research Station, Ananthapuramu and Garikapadu was taken upto study the adoption of raingun technology for supplemental irrigation to rainfed crop viz., pigeonpea. Raingun(Pelican with a discharge of 13,000 lit/hr, @ 4 kg/cm^2 operating pressure, with a throwing radius of 23m, uniformity of 71 % at field level) utilized for the sprinkling of supplemental irrigation to rejuvenate the productivity of the rainfed Pigeonpea and to achieve the doubling of the productivity.*

Result: *Experimental results revealed that, the application of 20mm supplemental irrigation at blossoming and pod development stages through raingun enhances the yield enhancement of 90.3 % (619 kg/ha) over the rainfed control (60 kg/ha) at Ananthapuramu.*

20 mm each at pre-flowering and Pod filling recorded higher seed yield compared to 10 and 30mm irrigation at Garikapadu.Flower and fruit drops were not noticed across the period of the experimentation due to the water jet hitting on the crop.

Keywords: *Pigeonpea, Low productivity, medium duration, terminal drought,Supplemental irrigation, Raingun, Yield Enhancement*

Introduction

In India, Pigeonpea is the second most important pulse crop and is predominantly grown under rainfed conditions. Pigeon pea with its tap root system was known to break the plough pans and was rightly called the ''biological plough'' (10). InIndia,pigeon pea (*Cajanus cajan L.*)is growing an area of 3.86mha with anannual production of of 2.90m tonnes and productivityis751 kg ha^{-1}(Anon.,2011).India accounts for 90 percent of the Pigeonpea area and production of the world.It is mainly grown in states of Maharashtra, Uttar Pradesh, Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu and these states constitute about 90 percent of the cultivated area in India. In dry farming areas of Andhra Pradesh, rainfall is not only scanty but also erratic. Thus, soil moisture becomes the most limiting factor in the production of pigeonpea. The area and production of Pigeonpea in Andhra Pradesh is 2.50 lakh ha and 1.19 lakh tonnes respectively, but the productivity of Pigeonpearemained stagnant for many years with a seed yield of 455 kg ha^{-1}(1).

However, the productivity of this crop is too low and almost static for the last five decades due to the cultivation of long-duration cultivars that are prone to climatic variations causing temporary water logging, drought and frost. In peninsular India, particular to Andhra Pradesh viz., Ananthapuramu district where long duration varieties predominate, terminal drought (reproductive period) is the major yield limiting factor (2).Farmer's livelihood is invariably linked with rain, particularly in drought-prone arid district of Ananthapuramu. Miniscule amount and unpredictable rainfall causing consecutive droughts was an immense challenge in the crop criticalstages leads to the moisture stress in the blossoming and grain development in the pod stage leads to the poor yields in the rainfed crops.

However, the rainfall is low, intensity is high, and causing prolonged dry spells during the crop growth period, thereby reducing the yields of rainfed pigeonpea. Being a long-day plant, it comes to flowering by fag end of October to the first week of November where the monsoon winds up as the flowering initiates. Supplemental irrigations at 50 days after sowing, bud blossoming and pod development higher the grain yields (3)). To curb of this issue efforts was made at the Agricultural

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Research Station, Ananthapuramu and Garikapadu to investigate the effect of supplemental irrigation through raingun.

Materials and Methods

Field experimentations were conducted in two sites viz., at Agricultural Research station,Ananthapuramu(14^0 41'latitude,77^0.40'longitude), Ananthapuramu districtduring *kharif*,2016 & 2017 in rainfed *alfisols*and Garikapadu ($16^0$53' latitude, 80^0.06' longitude), Krishna District during *kharif* 2018 and 2019 in sandy loam soils respectively.

At Agricultural Research Station, Ananthapuramu,during cropseasonan amount of 415.7mm of rainfall was recorded with monthly distribution of 154.6mm, 128.4mm, 38.7mm, 84mm, 0mm, 2.8mm and 7.2mm from June to December respectively. An amount of 616 mm and 620mm rainfall was received during the crop-growing period in 2018 and 2019 respectively at Garikapadu.

The source of the irrigation or moisture was given with the farm pond water harvested during the runoff events noticed during the 11^{th} (31.4mm) and 29^{th}(25.4mm) September 2016 at Ananthapuramu. whereas at second experimental site (Agricultural Research Station, Garikapadu) was an open well with 5 hp motor lifting device.

Parameter	Agricultural Research Station,Ananthapuramu	Agricultural Research Station,Garikapadu
Latitude and longitude	$14^041'$ &$77^0.40'$	$16^053'$ & $80^0.06'$
Actual rainfall (mm) during crop season	415.7	620.1
Normal seasonal Rainfall (mm) during crop season	478.6	725.6
Source of irrigation	Farm pond water (Farm Pond was filled during runoff events recorded on 11-09-2016 & 29-09-2016 viz., 31.4mm and 25.4 mm)	Open well with 5 hp motor
Initial soil status of Major nutrients	Nitrogen – Low Phosphorus – Medium Potassium – High	Nitrogen – Low Phosphorus – Medium to High Potassium – High

1. ARS, Ananthapuramu: The experiment was executed on large-sized plots in one-way ANOVA with supplemental irrigation treatments as enlisted

M1- Control (No supplemental Irrigation)

M2- 20 mm supplemental irrigation at flowering (One supplemental Irrigation)

M3-20 mm supplemental irrigation at flowering & Pod development (Two Supplemental Irrigation)

Rain gun Uniformity testing: The Pelican raingun with 14mm and 16 mm nozzles were selected for uniformity testing. Kirloskar 10hp diesel oil engine was used to discharge the water and 4inch HDPE water carrying pipes of 6m each 40 number (40 x 6m= 240m) were used up to the discharge point. The uniformity coefficient was computed by placing the catching can at 1m distance from the discharge point to extent of 30mts in all directions viz., east, west, north, and south respectively (totally 120 catch cans). The kilorskar oil engine was operated at $4kg/cm^2$ pressure constantly. The sum of the water collected at each catch can was quantified for each 15 min and the exercise was recurrent for 3 hrs with 14mm and 16mm nozzle of the raingun. The wind velocity was 11.2 kmph during the uniformity testing period.

Later on, the after the uniformity testing the water is allowed to discharge the water at the rate of 10mm and 20mm based on the discharge and throwing radius of the raingun. Growth parameters, yield attributes and yield in Pigeonpea viz., plant height (cm), stem girth (cm), no of branches, flower drop incidence and grain yield (kg/ha) was documented for the one supplemental irrigation and two supplemental irrigations.

2. ARS, Garikapadu: The experiment was executed in large-sized plots in split plot design with methods of irrigation as two main treatments and nine irrigation schedules as subplots at ARS, Garikapadu as discussed below.

Methods of irrigation: Two

M1: Rain gun method of irrigation

M2: Furrow method of irrigation

Irrigation schedules: Nine

S1: 10 mm at pre flowering

S2: 10 mm at pod filling

S3: 10 mm each at pre flowering and pod filling

S4: 20 mm at pre flowering

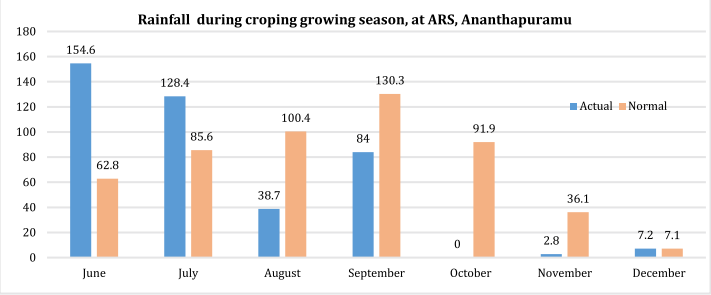
S5: 20 mm at pod filling

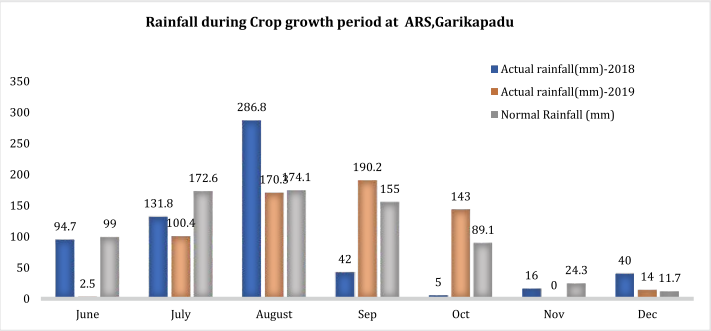
S6: 20 mm each at pre flowering and pod filling

S7: 30 mm at pre flowering

S8: 30 mm at pod filling

Data pertaining to Growth parameters, yield attributes and yield in Pigeonpea viz., plant height (cm), stem girth (cm), no of branches, flower drop incidence and grain yield (kg/ha) was documented.





RESULTS AND DISCUSSION

1. ARS, Ananthapuramu

Uniformity testing of Rain gun: The water collected in the 120 catch cans in all directions and the amount of water collected after 15 minutes was measured, and uniformity was estimated using the formula (5). (3)

Christiansen's uniformity coefficient =

$$\frac{100\ \%\ (1-\text{Average deviation from the average depth of Application})}{\text{overall average depth of Application}}$$

From the Christiansen's uniformity coefficient formula by using 16mm nozzle was 71 % uniformity and for the 14mm nozzle 73 % uniformity was recorded at the Agricultural Research station, Ananthapuramu farm with 11.2 kmph wind velocity during the experimentation.

Discharge and depth of irrigation studies: The raingun was operated at 4 kg/cm^{2}and water is allowed to discharge from the open farmpond at 240m stretch from the source of pumping to the outlet point. Throwing radius was calculated around the water hitting point on the ground across the diameter and finally average throwing radius was measured as meters.The discharge was measured using the water meter which was set up at one point before the discharge point. Based on the water meter reading 13,480 lit/hour discharged.

The depth of the irrigation or moisture was estimated by using this formula

Q = A X V

Q= discharge in liters per hour

A= Area covered (Rain gun area is in circular manner)= $A = \pi r^2$

V= volume of the water/ depth of water in mm/cm/m

Based on this equation

Q = A X V

13,480 = 3.14 x 23^2 x V

V = 8.11mm/hr

To discharge the 8mm approximately with the throwing radius of 23 m to an area of 1661m^2 it requires about an hour. As per the treatment it takes 2.5 hours to irrigate the field with the 20mm depth of the water for one supplemental irrigation.

Foot print of yield and other biometric parameters on Pigeonpea

1. Ananthapuramu: Pigeonpeacultivar PRG-176 (medium duration- 160 days) was sown on 21-07-2016 with the receipt of 17.2mm rainfall through tractor-drawn Ananta Pigeonpea planter with 90 cm X 20 cm spacing. The crop was grown luxuriantly with the soil moisture received by the succeeding rains after sowing.

Pigeonpeaentered the flowering stage in the first week of October with severe moisture stress. The treatments viz., one and two supplemental irrigations were imposed with the 20 days intervals i.e., 15th October and 5th November with respect to crop at blossoming and formation stages respectively(No rain was received since 1st October to end of the crop expect on 1st November recorded 2.8mm). The biometric and yield parameters were recorded in pigeon pea at 0-7 meters, 07-14 meters and 14-22 meters distance to study the disparitiesin the yield as tabulated in 1,2 mentioned below.

Highest plant height was recorded at 7-14m distance with 20mm supplemental irrigation at flowering followed by 0-7m distance and lowest noticed with control and the same trend receded with respect to the stem girth also. There is no much variation among the biometric parameters noticed. There were significant variations in the yields due to the impact of one supplemental irrigation in the Pigeonpea at the time of flowering. (466 kg/ha) when compared with the control (60 kg/ha) with 83.5 % yield increase over the control. However, within those higher yields were reported with the lesser distance (0-7m),followed by later distances viz., (7-14m and 14-22m) due to more moisture and uniformity of the water distribution ejected through the rain gun.

2.Garikapadu: During 2018, providing 20 mm irrigation each at pre-flowering and pod filling stages (1195 kg/ha); 20 mm irrigation at pre-flowering (1117 kg/ha) and 10 mm each at pre-flowering and pod filling stages (1113 kg/ha) recorded higher seed yield in redgram. Similar results are recorded in 2019 also by using rain gun.

During the year 2019, providing 20 mm irrigation each at pre-flowering and pod filling stages (1366 kg/ha); 20 mm irrigation at pre-flowering (1325 kg/ha) and 10 mm each at pre-flowering and pod filling stages (1292 kg/ha) recorded higher seed yield in redgram. When irrigation water availability is more and the growth of redgram doesn't facilitate for furrow irrigation, rain gun method can be adopted. Though 30 mm each at pre-flowering and pod filling stages also recorded higher yields of 1313 kg/ha, 3.0 lakh liters/ha water is required. The pre-flowering stage is found to be more responsive stage for protective irrigation.

The application of 20mm at flowering and pod development stages through raingun enhances the yield advantage of 88 % (619 kg/ha) over the control (60 kg/ha).(7). The trend continued the same with the two supplemental irrigations to Pigeonpea on each at flowering and pod development. Though the yield enhancement was more (619 kg/ha) when compared with the control (60 kg/ha), one supplemental irrigation at flowering (466 kg/ha). There is a significant increase of 90.3 % over the control. More specifically, net benefits with supplemental irrigation were improved by about 3 times for rice, 4-times for pulses and 6-times for oilseeds (3,8)). Similar findings were reported and revelaed that supplemental irrigation enhances the yields(6).

The variations among the different distances with in the throwing radius of raingun followed the same trend either withone or two irrigations. The same trend viz higher yields were recorded with the lesser distance (0-7m) followed by later distances viz., (7-14m and 14-22m) due to more moisture and uniformity of the water distribution ejected through the raingun. Flower and fruit drop were not noticed across the period of the experimentation due to water jet hitting on the crop. Hence, by supplying irrigation at critical stages may enhance the yields in rainfed pigeonpea. These results are in similar line with the following authors (4) (10). noted that supplemental irrigation with harvested rainfall could bridge the prolonged dry spells in Kenya which increased the yields of onions from 1.6 t/ha to 11.9t/ha and kales from 6.4 t/ha to 15.8 t/ha.

Cost economics of the supplemental Irrigation

Ananthapuramu: The cost of each supplemental irrigation is 1500 INR only. Rain gun supplemental irrigation of 20 mm at one each flowering and pod development recorded the highest net returns of 18,845 INR followed by rain gun supplemental irrigation of 20 mm at flowering with a net return of 25,630 INR and negative net returns (- 8900 INR) was recorded with control (no supplemental irrigation treatment). The highest B:C ratio (2.24) was documented with the 20 mm supplemental irrigation of each at the flowering and pod development stage and lowest documented with control (no supplemental irrigation treatment).

Water use efficiency was highest at 20 mm supplemental irrigation of each at flowering and pod development stage (1.42) and lowest was with control (0.14).

Garikapadu: The cost of each supplemental irrigation is 1000 INR only.Rain gun supplemental irrigation of 20 mm pre flowering and recorded the highest net returns of 47,800 INR followed by rain gun supplemental irrigation of 20 mm each at pre-flowering and pod filling recording the same net returns but highest B:C ratio 4.49 was recorded with 20 mm each at pre flowering followed by rain gun supplemental irrigation of 10 mm each at pre flowering and pod filling stage recorded.Highest B:C ratio (2.24) was documented with the 20 mm supplemental irrigation of each at the flowering and pod development stage and lowest was documented with control (no supplemental irrigation treatment). Water use efficiency was highest at 20 mm supplemental irrigation of each at flowering and pod development stage (1.42) and lowest was with control (0.14).

CONCLUSION

Pigeonpea across the season with one and two supplemental irrigations through rain guns was given to PRG-176 as a pure crop.

There is a remarkable yield increase was recorded in one and two irrigations over the control. However, in both one and two irrigations 0-7mts throwing radius point indicated the higher yield rather than the other distances. The reason might be the higher uniformity was reported in 0-7m. Flower drop was observed to minor extent during supplemental irrigation with raingun. The pre-flowering stage is found to be more responsive stage for protective irrigation. When irrigation water availability is more and growth of Pigeonpea doesn't facilitate for furrow irrigation, rain gun method can be adopted. When the availability of irrigation water is scarce and the growth of Pigeonpea facilitates for movement of a tractor-mounted tanker, furrow irrigation is the better option. Therefore, better control and management of water is a win-win solution that helps to increase water available to crops while reducing the negative consequences caused due to prolonged dry spells.

Future scope of the study

Conflict of interest: Authors declare that there is no conflict of intrest.

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Table: 1. Effect of one supplemental irrigation yield of Pigeonpea at flowering during kharif, 2016 at ARS, Ananthapuramu.

Quantity of the Irrigation	Distance from the Raingun (m)	Plant height (cm)	Stem girth (mm)	No of primary branches	Grain yield (kg/ha)	% Increase over control
No Supplemental irrigation	**Control**	**133.4**	**10.58**	**7**	**60**	**-**
20mm supplemental irrigation at flowering	0-7 m	144.6	12,00	8	553	89.2
	7-14 m	148.2	10.97	8	478	87.4
	14-22 m	141.0	13.23	7	367	83.7
Mean		**144.6**	**12.10**	**8**	**466**	**83.5**

Table: 2. Effect of two Supplemental Irrigation on yield of Pigeonpea during kharif,2016 at ARS, Ananthapuramu

Quantity of the Irrigation	Distance from the Raingun (m)	Plant height (cm)	Stem girth(mm)	No of primary branches	Grain yield (kg/ha)	% Increase over control
No Supplemental irrigation	**Control**	**133.4**	**10.58**	**7**	**60**	**-**
20mm supplemental irrigation at one each flowering and pod development	0-7 m	144.6	13.26	9	704	91.4
	7-14 m	143.0	12.90	8	648	90.7
	14-22 m	141.0	13.23	7	506	88.1
Mean		**142.9**	**13.13**	**8**	**619**	**90.3**

Table: 3. Seed yield of redgram (kg/ha) as influenced by method and depth of irrigation at ARS, Garikapadu

Treatments	Raingun Irrigation								Raingun irrigation	Furrow Irrigation	Rainfed
	Distance from raingun (m)						Mean				
	0-5		05-10		10-16						
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**Mean**	**Mean**	**2019**
S1 : 10 mm at pre-flowering	1153	1200	881	1152	952	1111	992	1229	1111	-	
S2 : 10 mm at pod filling	548	1105	588	1119	413	1079	516	1200	858	-	
S3 : 10 mm each at pre- Flowering and Pod filling	1269	1310	1157	1343	913	1321	1113	1333	1223	1367	
S4 : 20 mm at pre- flowering	867	1229	931	1271	1554	1377	1117	1343	1230	-	
S5 : 20 mm at pod filling	348	1167	600	1229	694	1079	547	1219	883	-	1083
S6 : 20 mm each at pre- flowering and Pod filling	1314	1562	981	1390	1288	1147	1195	1324	1260	1357	
S7 : 30 mm at pre-flowering	367	1214	507	1200	500	1381	458	876	667	-	
S8 : 30 mm at pod filling	710	1167	876	1105	841	1095	809	981	895	-	
S9 : 30 mm each at pre- flowering and Pod filling	648	1257	890	1357	813	1325	784	1038	911	1319	

Table: 04. Hundred seed weight (g) of redgram as influenced by method and depth of irrigation at ARS, Garikapadu

Treatments	Raingun Irrigation								Rain gun Irrigation	Furrow Irrigation	Rainfed
	Distance from raingun (m)						Mean		Mean	Mean	2019
	0-5		05-10		10-16						
	2018	2019	2018	2019	2018	2019	2018	2019			
S1: 10 mm at pre-flowering	10.4	11.1	10.8	11.2	11.6	11.3	10.9	11.2	11.05	-	
S2: 10 mm at pod filling	10.6	11.1	9.9	10.9	10.9	10.3	10.5	10.8	10.65	-	
S3: 10 mm each at pre- Flowering and Pod filling	11.2	11.2	11.2	11.7	10.8	11.4	11.1	11.4	11.25	10.3	
S4: 20 mm at pre- flowering	10.3	11.1	10.8	11.3	10.6	11.2	10.6	11.2	10.9	-	
S5: 20 mm at pod filling	10.8	11.4	10.7	10.9	10.2	11.3	10.6	11.2	10.9	-	10
S6: 20 mm each at pre- flowering and Pod filling	11	10.7	9.7	10.4	10.7	11	10.5	10.7	10.6	10.2	
S7: 30 mm at pre-flowering	11	11.3	11.5	11.2	10.8	11.1	11.1	11.2	11.15	-	
S8: 30 mm at pod filling	10.2	11.3	10.9	10.9	10.1	11.7	10.4	11.3	10.85	-	
S9: 30 mm each at pre- flowering and Pod filling	10.8	11	10.5	10.5	9.9	10.4	10.4	10.6	10.5	10.8	

Table: 05. Cost economics of the raingun irrigation at ARS, Garikapadu

Treatments	Yield (kg/ha)	Cost of Cultivation (Rs/ha)	Cost of Irrigation (Rs/ha)	Total Cost of Cultivation (Rs/ha)	Gross Returns (Rs/ha)	Net Returns (Rs/ha)	B:C ratio	WUE (RWUE+IWUE)
Agricultural Research Station, Ananthapuramu								
No supplemental irrigation	60	12200	0	12200	3300	-8900	0.27	0.14
20mm supplemental irrigation at flowering	466	12200	1500	13700	25630	11930	1.85	1.08
20mm supplemental irrigation at one each flowering and pod development	619	12200	3000	15200	34045	18845	2.24	1.42
Agricultural Research Station, Garikapadu								
S1 : 10 mm at pre-flowering	1111	12,200	1000	13,200	55550	42,350	4.21	1.77
S2 : 10 mm at pod filling	858	12,200	1000	13,200	42900	29,700	3.25	1.37
S3 : 10 mm each at pre- Flowering and Pod filling	1223	12,200	2000	14,200	61150	46,950	4.31	1.95
S4 : 20 mm at pre- flowering	1230	12,200	1500	13,700	61500	47,800	4.49	1.93
S5 : 20 mm at pod filling	883	12,200	1500	13,700	44150	30,450	3.22	1.38
S6 : 20 mm each at pre- flowering and Pod filling	1260	12,200	3000	15,200	63000	47,800	4.14	1.97
S7 : 30 mm at pre-flowering	667	12,200	2000	14,200	33350	19,150	2.35	1.03
S8 : 30 mm at pod filling	895	12,200	2000	14,200	44750	30,550	3.15	1.38
S9 : 30 mm each at pre- flowering and Pod filling	911	12,200	4000	16,200	45550	29,350	2.81	1.41

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