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Growth, physiological parameters and yield analysis in redgram (*Cajanus cajan*) as influenced by tillage practices and supplemental drip irrigation

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Abstract
Field experiment was conducted in two consecutive growing seasons at Agricultural Engineering College and Research Institute, Kumulur, Tamil Nadu to evaluate the tillage practices, crop residue and supplemental irrigation through drip irrigation in redgram under rainfed condition. The experiment was laid out in strip plot design with three replications. The main plot treatments were conventional tillage, minimum tillage without crop residue, minimum tillage with crop residue @ 5 t ha^{-1} and minimum tillage with crop residue @ 10 t ha^{-1}. The sub plot treatments were control (without irrigation), supplemental drip irrigation 4, 6, 8 and 10 times during the cropping period. Tillage practices and crop residue with supplemental drip irrigation practices could potentially lead to significant difference in growth parameters, physiological characters, yield attributes and maximum yield 1321, 1234 kg ha^{-1} of redgram in both the seasons by application of minimum tillage with crop residue 10 t ha^{-1} + supplemental drip irrigation ten times. Therefore, minimum tillage (one pass of mouldboard plough followed by two passes of disk harrow) with crop residue 10 t ha^{-1} + supplemental irrigation through drip irrigation ten times was found to be more appropriate and profitable to improving yield of redgram under rainfed condition.

Keywords: Crop residue, redgram, supplemental irrigation, tillage and water content

Introduction

Soil management practices, cropping systems, and weather conditions influence soil health. Therefore, a healthy soil that is well managed can increase soil water infiltration and storage, storage and supply of nutrients to plants, microbial diversity, and soil carbon storage. Soil organic matter (SOM) is a central soil property that is heavily affected by management practices, which in turn influences soil physical, biological, and chemical functions. Soil quality (SQ) highly depends on its structure, natural productivity, and human influence. Soil organisms are important elements for preserved ecosystem biodiversity and services thus assess functional and structural biodiversity in arable soils is interest. Main threats to soil biodiversity occurred by mechanical impacts (soil compaction, soil tillage) and chemical stress (plant protection measures) in agricultural management.

Tillage is one of the major management practices affecting soil physical parameters. The influence of tillage systems on the total soil organic matter (OM) content is detectable only after several years of its application. Microbial activity may respond to disturbances on a shorter period of time than those based on physical or chemical properties. As a consequence, microbiological properties such as soil enzyme activities have been suggested as potential indicators of SQ (Saviozzi *et al.*, 2001) [20] because of their rapid response to changes in soil management (Kandeler *et al.*, 1999) [10]. In many cases, both bacteria and fungi were more abundant under no-tillage than conventional tillage (Helgason *et al.*, 2009) [8].

Tillage systems affect the soil physical and chemical environment in which soil organisms live, thereby affecting soil organisms in different ways (Klavdivko, 2001) [11]. Numerous studies in temperate regions have shown that decreasing tillage intensity results in higher organic C and N and improved soil quality (SQ) (Soon *et al.*, 2001) [21]. Conservation tillage practices (reduced or no-tillage) result in increasing enzyme activities (Acosta-Martinez *et al*., 2003) [1], microbial biomass (Franzluebbers *et al*., 1995), and fungal and bacteria dominance under NT (Helgason *et al.*, 2009) [8]. Suitable soil management can be practiced through conservation tillage (including zero tillage), high crop residue return and crop rotation.

Minimum-Tillage (MT) is the most adapted conservation tillage system, which involves minimal disturbance of the surface residue.

In dry areas mostly shortage of soil moisture occurs during the most sensitive growth stages like flowering and grain filling stage of the crops. As a resulting is poor crop growth and yield. Supplemental irrigation (SI), with limited amount of water, when applied during the critical crop growth stages, can result in substantial improvement in yield and water productivity. Hence SI is an effective method to alleviate the adverse impact of soil moisture stress during dry spells on the yield of rainfed crops (Oweis and Hachum. 2006) [17].

Pigeonpea is one of the important tropical pulse crop of India and ranks seconds after chickpea in area and production. Food value of pigeonpea is protein (22.3%), fat (1.7%), minerals (3.5%), fiber (1.5%) and carbohydrates (57.6%). It is commonly known as red gram or Arhar and grown in *kharif* as well as in *Rabi* season. The area under pigeonpea crop in India is 4.0 million ha with the production of 3.01million tones among the pulses in India (Anon, 2016) [2].

Keeping this in view, the present investigation was undertaken to study the combined effect of tillage, crop residue incorporation and supplemental irrigation methods on the growth, physiological and yield of redgram in Tamil Nadu.

Materials and Methods

A field experiment was carried out for two consecutive growing seasons at Agricultural Engineering College and Research Institute, Kumulur, Tamil Nadu. The experimental site is geographically situated at 10.56^0 North latitude and 78.49^0 East longitudes and at an altitude of 78 m above MSL. The soil was sandy loam in texture with pH 7.71. The fertility status of the soil was low, medium and high in the available N, P_2O_5, and K_2O, with the values of 212, 20 & 575 kg ha^{-1} respectively. The main plot treatments were conventional tillage, minimum tillage without crop residue, minimum tillage with crop residue @ 5 t ha^{-1} and minimum tillage with crop residue @ 10 t ha^{-1}. The sub plot treatments were (without irrigation) control, supplemental drip irrigation 4, 6, 8 and 10 times during the cropping period. The experiment was laid out in a strip plot design with three replications.

Conventional tillage included one pass of mouldboard plough to a depth of 15 cm and was followed by two passes of disk harrowing. Minimum tillage included only one pass of disk harrowing. The treatments were carried out on the same plots in the growing seasons. In both growing seasons, one of the most popular and short duration variety CO(Rg) 7 was sowing manually on paired row spacing of 90 +30 x 30 cm (totally there were two rows per plot). Before sowing a uniform fertilizer schedule was followed at the rate of 12.5:25:12.5 kg of N, P_2O_5 and K_2O ha^{-1}, out of this full dose of P, 50 per cent of N and K was applied as basal dose at sowing and the balance 50 per cent of N and K was applied as top dressing at 25 DAS.

Pre emergence herbicide pendimethalin @ 0.75 kg a.i ha^{-1} was applied for redgram, as on the 3 DAS for effective control of weeds. The herbicide spray fluid was sprayed uniformly over the soil surface using a hand operated Knap-sack sprayer fitted with deflector type nozzle. Hand weeding was done on 30 DAS in redgram. During the growing season, the insecticides and fungicides were applied according to recommendations by the state agricultural university (SAU). All other necessary operations except those under study were kept normal and uniform for all the treatments.

The supplemental irrigation was given to the crop at the time of moisture stress period, which was determined based on the visual symptom (Wilting of plants). In study period four, six, eight and ten supplemental irrigations were given at various time periods. The water was pumped by motor from farm pond and supplied to crops through drip irrigation system at a depth of 3 cm.

Observations on growth characters such as plant height and dry matter production were recorded at 30, 60, 90 DAS and at harvest from five randomly selected plants in each plot. The samples were collected from sampling rows in each plot for dry matter production and were used for the estimation of DMP. The data on yield parameters and yield were also recorded.

Result and Discussion

Effect of treatments on plant height

Growth and development in plants are a consequence of excellent coordination of several processes operating at different growth stages of plant. The growth of redgram influenced by various tillage treatments has been elucidated through the positive response on plant height.

The growth parameters of redgram were significantly influenced by tillage and crop residue with supplemental irrigation through drip irrigation. The growth parameters were not influenced by treatments at 30 DAS. Among tillage and crop residue treatments, minimum tillage with crop residue 10 t ha^{-1} recorded significantly higher plant height (Table 1&2) (75.3, 110.5, 118.6 cm and 77.1, 113.6, 118.7 cm at 60, 90 DAS and at harvest during 2012 and 2013, respectively). Regarding irrigation practices, supplemental irrigation at 10 times was recorded higher plant height than without supplemental irrigation plot. Residue cover is a major factor in determining soil temperature and availability of soil moisture (Beyaert *et al.,* 2002) [3]. These factors would have favored the growth of redgram under minimum tillage with crop residue and supplemental irrigation through drip system.

Table 1: Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on plant height (cm) of red gram during 2012

Treatments	60 DAS					90 DAS					Harvest				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	64.5	65.7	66.3	67.2	65.9	88.3	91.3	93.3	97.5	92.6	93.4	94.4	95.8	97.1	95.2
S_2	66.4	68.7	69.6	70.5	68.8	92.7	94.5	95.3	100.2	95.7	95.3	97.2	98.4	106.4	99.3
S_3	67.2	71.0	70.3	73.6	70.5	95.3	98.0	101.1	104.0	99.6	98.0	101.2	109.4	118.3	106.7
S_4	68.7	69.4	70.0	81.2	72.3	97.2	103.0	109.0	118.0	106.8	101.1	105.5	116.4	130.3	113.3
S_5	69.2	72.3	73.4	84.0	74.7	103.0	110.0	119.0	133.0	116.3	106.3	112.3	124.6	141.0	121.1
Mean	67.2	69.4	69.9	75.3		95.3	99.4	103.5	110.5		98.8	102.1	108.9	118.6	

	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
T	1.6	4.0	3.6	8.7	3.8	9.4
S	1.9	4.4	4.2	9.6	3.6	8.3
T at S	2.8	6.5	4.4	10.4	4.5	10.7
S at T	2.9	6.7	4.9	11.2	4.3	9.8

Table 2: Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on plant height (cm) of red gram during 2013

Treatments	60 DAS					90 DAS					Harvest				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	61.5	60.1	66.5	68.2	64.1	87.2	88.3	91.9	99.1	91.6	90.9	91.9	94.3	102.2	94.8
S_2	63.4	62.5	68.5	73.5	67.0	91.3	90.2	99.1	105.5	96.5	93.3	95.2	97.3	110.1	99.0
S_3	67.1	66.8	71.3	77.4	70.7	96.3	94.3	106.7	113.2	102.6	98.4	97.0	107.3	116.3	104.8
S_4	67.9	71.2	70.5	81.2	72.7	94.4	92.0	111.2	119.4	104.3	100.1	101.1	118.2	126.8	111.6
S_5	70.7	69.2	74.2	85.4	74.9	99.1	100.2	120.4	131.0	112.7	104.8	114.3	127.5	138.3	121.2
Mean	66.2	65.9	70.2	77.1		93.6	93.0	105.8	113.6		97.5	99.9	108.9	118.7	

	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
T	2.1	5.1	4.5	11.1	3.8	9.3
S	2.5	5.9	3.4	7.7	4.0	9.2
T at S	2.5	5.9	5.4	12.8	4.6	10.8
S at T	2.9	6.7	4.4	10.2	4.7	10.8

With interaction effect, tillage practice with crop residue and supplemental irrigation through drip system had significant influence on plant height at 60, 90 DAS and at harvest stage during 2011-12 and 2012-13. Minimum tillage with crop residue

@ 10 t ha^{-1} combination with supplemental irrigation through drip system 10 times (T_4S_5) recorded higher value for plant height (84.0, 133.0 and 141.0 cm; 85.4 131.0 and 138.3 cm) at 60, 90 DAS and harvest stage during both the years, respectively. At 30 DAS, the interaction effect was not significant between tillage practices with crop residues and supplemental irrigation practices during both the years.

Effect of treatments on dry matter production

Tillage and crop residue with supplemental irrigation through drip irrigation significantly influenced the dry matter production (Table 3&4). Among tillage and crop residue treatments, minimum tillage with crop residue 10 t ha^{-1} recorded significantly higher dry matter production (2425, 2779, 3536 kg ha^{-1} and 2428, 2810, 3022 kg ha^{-1}) at 60, 90 DAS and at harvest during 2012 and 2013, respectively. Among irrigation practices, supplemental irrigation at 10 times was recorded higher dry matter production in respective stages during both the seasons and it was comparable with supplemental irrigation at 8 times was recorded higher dry matter production than that in without supplemental irrigation plot.

Table 3: Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on dry matter production (kg ha^{-1}) of redgram during 2012

Treatments	60 DAS					90 DAS					Harvest				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	1867	1873	1902	1955	1899	2075	2106	2245	2375	2200	2233	2264	2457	2587	2385
S_2	1903	1942	1998	2402	2061	2245	2345	2401	2543	2384	2403	2503	2613	2755	2569
S_3	1945	1996	2103	2456	2125	2415	2400	2512	2691	2505	2573	2558	2724	2903	2690
S_4	1987	2007	2301	2587	2221	2497	2456	2654	2964	2643	2525	2559	2743	2991	2705
S_5	1998	2156	2389	2725	2317	2604	2697	2845	3324	2867	2655	2614	2866	3176	2928
Mean	1940	1995	2139	2425		2367	2401	2531	2779		2762	2855	3057	3536	

	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
T	57	139	82	201	96	235
S	65	149	105	243	101	233
T at S	74	175	112	263	139	328
S at T	80	183	129	297	141	324

Table 4: Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on dry matter production (kg ha^{-1}) of redgram during 2013

Treatments	60 DAS					90 DAS					Harvest				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	1802	1847	1945	1993	1897	2045	2114	2245	2387	2198	2203	2271	2457	2599	2383
S_2	1894	1918	2032	2123	1992	2107	2310	2410	2514	2335	2265	2468	2622	2726	2520
S_3	1953	1991	2298	2435	2169	2248	2432	2689	2746	2529	2406	2590	2901	2958	2714
S_4	1992	2065	2432	2701	2298	2389	2501	2710	2947	2637	2547	2659	2922	3159	2822
S_5	2102	2194	2562	2889	2437	2547	2710	2948	3458	2916	2705	2868	3160	3670	3101
Mean	1949	2003	2254	2428		2267	2413	2600	2810		2425	2571	2812	3022	2708

	SEd	CD (P=0.05)	SEd	CD (P=0.05)	SEd	CD (P=0.05)
T	63	155	98	240	113	277
S	76	176	110	254	127	294
T at S	89	208	124	293	170	400
S at T	97	224	133	306	177	408

With regard to interaction effect, in a given tillage with crop residue treatment and supplemental drip irrigation, minimum tillage with crop residue 10 t ha^{-1} + supplemental drip irrigation 10 times registered significantly higher dry matter production at 120 DAS and at harvest during both the years of study. Mahalakshmi *et al.* (2011) [14] reported that pigeonpea under drip irrigation with 0.8 Epan throughout the crop period recorded higher total dry matter production (3731 kg ha^{-1}) at harvest.

This might be due to the reason that minimum tillage conserved more soil moisture and crop residues have potential to increase of soil organic matter and nutrient levels, moderation of soil temperature and augmented soil biological activity, which provided better growing environment for increased plant height. Minimum tillage indirectly defines the species composition of the soil microbial community by improving retention of soil moisture and modifying soil temperature (Krupinsky *et al.*, 2002) [12].

Effect of treatments on Physiological parameters

Relative leaf water content: among tillage practice with crop residues, the minimum tillage with crop residue @ 10 t ha^{-1} recorded significantly higher relative leaf water content (RLWC) of 77.1 and 77.1 per cent at pod formation stage, during 2011-12 and 2012-13, respectively. Supplemental irrigation had no significant influence on relative leaf water content at flowering stage during both the years. As far as irrigation practices, supplemental irrigation through drip system 10 times recorded higher relative leaf water content of 76.0 and 77.9 per cent at pod formation stage, respectively first and second season (Table 5&6). Minimum tillage with crop residue @ 10 t ha^{-1} combination with supplemental irrigation through drip system 10 times recorded significantly higher relative leaf water content of 84.2 per cent at pod formation stage during 2011-12.

Table 5: Effect of tillage practice with crop residue and supplemental irrigation through drip system on physiological parameters Relative leaf water content (RLWC) and Chlorophyll stability index (CSI) of redgram

Treatments	2012				2013			
	Flowering		Pod development		Flowering		Pod development	
	RLWC (%)	CSI	RLWC (%)	CSI	RLWC (%)	CSI	RLWC %)	CSI
Tillage practice with crop residue								
T_1	61.8	52.4	68.9	52.7	61.3	50.0	71.8	50.1
T_2	62.0	52.7	67.3	50.4	63.1	51.2	70.8	52.5
T_3	63.4	54.9	72.9	56.1	63.3	49.9	74.2	56.8
T_4	64.6	55.4	77.1	57.9	63.4	50.6	77.1	59.8
SEd	1.7	1.2	1.6	1.3	1.7	1.4	1.8	1.3
CD (P = 0.05)	NS	NS	4.01	3.26	NS	NS	4.08	3.16
Supplemental irrigation with drip system								
S_1	61.9	52.3	67.3	50.8	61.2	48.3	69.5	50.6
S_2	62.7	52.9	69.3	52.6	62.5	49.8	71.5	52.8
S_3	62.9	53.8	71.5	54.1	62.8	50.9	73.2	54.7
S_4	63.7	54.9	73.5	56.0	63.4	52.2	75.2	56.9
S_5	63.7	55.4	76.0	58.0	64.1	51.0	77.9	58.9
SEd	2.1	1.4	1.8	1.6	2.1	1.6	1.9	1.4
CD (P = 0.05)	NS	NS	4.2	3.6	NS	NS	4.5	3.3
Interaction	NS	NS	S	NS	NS	NS	NS	S

Table 6: Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on physiological parameters of redgram at pod development stage

Treatments	RLWC (%) (2012)					CSI (2013)				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	66.2	63.6	68.3	71.3	67.3	47.2	48.2	52.7	54.3	50.6
S_2	67.2	65.5	70.2	74.2	69.3	47.3	50.3	55.3	58.3	52.8
S_3	68.7	68.2	72.8	76.4	71.5	49.3	52.8	57.6	59.2	54.7
S_4	70.2	68.8	75.7	79.3	73.5	52.1	55.5	57.9	62.1	56.9
S_5	72.1	70.3	77.3	84.2	76.0	54.3	55.9	60.3	65.3	59.0
Mean	68.9	67.3	72.9	77.1		50.1	52.5	56.8	59.8	

	SEd	CD (P=0.05)	SEd	CD (P=0.05)
T	1.6	4.0	1.3	3.2
S	1.8	4.2	1.4	3.3
T at S	2.0	4.6	1.5	3.4
S at T	2.1	4.9	1.6	3.6

Chlorophyll Stability Index: Combination of tillage practice with crop residue and supplemental irrigation practices had significant influence on chlorophyll stability index at pod development stage during 2012-13. There was interaction between tillage practice with crop residue and supplemental irrigation through drip practices had significant influence on relative leaf water content and chlorophyll stability index at pod formation stage. Minimum tillage with crop residue @ 10 t ha^{-1} combination with supplemental irrigation through drip system 10 times recorded significantly higher relative leaf water content at pod formation stage. Under sever water stress, the CSI decreased with increase in water stress in most of the genotypes of maize (Meena Kumari *et al.*, 2004) [15].

Leaf Stomata: Minimum tillage with crop residue @ 10 t ha^{-1} recorded higher number of epidermal cells of 33.6 and 35.1 during 2011-12 and 2012-13, respectively (Table 7). Less number of epidermal cells was recorded in conventional tillage during both the years. Supplemental irrigation through drip system 10 times recorded significantly higher number of epidermal cells of 33.6 and 35.3 during 2011-12 and 2012-13 respectively. Same results are found in stomata density. Tillage practice with crop residue and supplemental irrigation practices had no significant influence on stomata index during both the years.

Table 7: Effect of tillage practice with crop residue and supplemental irrigation through drip system on leaf stomata of redgram

Treatments	2012			2013		
	Number of epidermal cells (No. mm^{-2})	Stomatal density (No. mm^{-2})	Stomatal index	Number of epidermal cells (No. mm^{-2})	Stomatal density (No. mm^{-2})	Stomatal index
Tillage practice with crop residue						
T_1	30.9	1.39	4.29	31.8	1.67	4.98
T_2	30.5	1.40	4.37	32.7	1.74	5.05
T_3	32.6	1.50	4.38	34.5	1.80	4.96
T_4	33.6	1.56	4.43	35.1	1.86	5.04
SEd	0.8	0.04	0.08	0.8	0.04	0.10
CD (P = 0.05)	2.0	0.09	NS	1.91	0.10	NS
Supplemental irrigation with drip system						
S_1	30.1	1.33	4.23	31.7	1.65	4.94
S_2	31.1	1.41	4.32	32.7	1.72	4.99
S_3	32.0	1.46	4.36	33.5	1.78	5.00
S_4	32.8	1.52	4.43	34.3	1.83	5.01
S_5	33.6	1.58	4.49	35.3	1.86	5.06
SEd	0.9	0.04	0.10	0.9	0.06	0.11
CD (P = 0.05)	2.2	0.10	NS	2.0	NS	NS
Interaction	NS	NS	NS	NS	NS	NS

Effect of treatments on yield attributes and yield

Minimum tillage with crop residue @ 10 t ha^{-1} in combination with supplemental irrigation through drip system 10 times recorded higher number of pods plant^{-1}, redgram grain yield and harvest index in both the years. Minimum tillage with crop residue @ 10 t ha^{-1} in combination with supplemental irrigation through drip system 10 times recorded higher redgram yield of 1321 and 1234 kg ha^{-1} during 2011-12 and 2012-13, respectively (Table 8 & 9).

Table 8: Effect of tillage practice with crop residue and supplemental irrigation through drip system on yield attributes of redgram

Treatments	2012					2013				
	Number of pods plant^{-1}	Number of seeds pod^{-1}	100 weight (g)	Grain yield (kg ha^{-1})	Harvest index	Number of pods plant^{-1}	Number of seeds pod^{-1}	100 weight (g)	Grain yield (kg ha^{-1})	Harvest index
Tillage practice with crop residue										
T_1	52.8	4.0	7.72	901	0.30	50.5	3.9	7.69	795	0.27
T_2	60.1	4.1	7.73	957	0.30	54.6	4.1	7.75	829	0.28
T_3	66.1	4.1	8.04	992	0.32	60.5	4.0	8.03	890	0.28
T_4	73.6	4.0	8.19	1098	0.32	67.7	4.1	8.17	977	0.28
SEd	2.6	0.2	0.21	45	0.004	1.9	0.1	0.22	40	0.002
CD (P = 0.05)	6.4	NS	NS	111	0.10	4.6	NS	NS	97	0.006
Supplemental irrigation with drip system										
S_1	50.1	3.8	7.62	816	0.30	47.1	3.8	7.62	772	0.26
S_2	56.8	3.9	7.86	961	0.31	53.0	3.9	7.69	812	0.27
S_3	62.6	4.2	7.97	996	0.31	58.0	4.1	7.94	861	0.28
S_4	68.8	4.2	8.12	1044	0.32	63.0	4.1	8.16	885	0.29
S_5	77.5	4.1	8.10	1118	0.32	70.5	4.1	8.13	1022	0.30
SEd	2.9	0.2	0.2	44	0.003	2.4	0.1	0.25	48	0.004
CD (P = 0.05)	6.7	NS	NS	102	0.007	5.4	NS	NS	110	0.008
Interaction	S	NS	NS	S	S	S	NS	NS	S	S

Table 9: Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on yield attributes and grain yield of redgram during 2012

Treatments	Number of pods plant^{-1}					Grain yield kg ha^{-1}				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	46.2	48.3	50.7	55.3	50.1	789	802	824	850	816
S_2	49.2	53.4	58.4	66.3	56.8	890	932	984	1037	961
S_3	50.2	60.2	65.4	74.6	62.6	920	975	1003	1085	996
S_4	55.2	65.2	74.8	80.0	68.8	946	990	1045	1195	1044
S_5	63.4	73.2	81.3	92.0	77.5	960	1087	1103	1321	1118
Mean	52.8	60.1	66.1	73.6		901	957	992	1098	

	SEd	CD (P=0.05)		SEd	CD (P=0.05)
T	2.6	6.4		46	111
S	2.9	6.7		44	102
T at S	3.6	8.4		58	138
S at T	3.8	8.7		57	130

Table 10: Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on yield attributes of redgram during 2013

Treatments	Number of pods plant^{-1}					Grain yield kg ha^{-1}				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	44.6	46.2	47.2	50.4	47.1	717	770	795	805	772
S_2	46.6	49.7	53.4	62.4	53.0	790	793	810	856	812
S_3	49.8	52.4	60.8	69.2	58.0	835	810	835	965	861
S_4	52.1	59.3	67.0	73.4	63.0	764	834	967	1023	885
S_5	59.3	65.6	74.2	83.0	70.5	870	938	1045	1234	1022
Mean	50.5	54.6	60.5	67.7		795	829	890	977	

	SEd	CD (P=0.05)	SEd	CD (P=0.05)
T	1.9	4.6	40	97
S	2.4	5.4	48	110
T at S	2.8	6.5	49	115
S at T	3.1	7.1	55	127

There were reports on irrigation to redgram at different growth stages depending on water availability to improve the seed yield. Tomar (2001) [23] observed that the scheduling of irrigation at IW/CPE ratio 0.5 at branching, flowering and pod-development stages resulted in a significant higher grain yield of pigeonpea over two irrigations at branching and pod development stages. Pramod (2007) [18] reported that seed yield of pigeonpea (16.51 q ha^{-1}) with two irrigations was significantly higher than one irrigation (14.33 q ha^{-1}) and control (10.96 q ha^{-1}) with protective irrigation under Raichur condition.

By adopting drip irrigation in pigeonpea at farmer's field, the highest grain yield of 33 q ha^{-1} was recorded in Hingne village of Jalgaon district in Maharashtra (Latha *et al.*, 2012) [13]. NPRC, (2013) [16] noticed that the scientist studied regarding optimizing irrigation schedule for short and long duration redgram under drip system in various centers, the results revealed that among short duration varieties studied, Co (Rg) 7 recorded higher grain yield of 1114 kg ha^{-1} followed by VBN (Rg) 3 with irrigation at 75 per cent. Among long duration varieties, LRG 41 recorded higher grain yield of 1710 kg ha^{-1} with irrigation at 75 percent. Bouma *et al*. (2005) [5] showed that upon availability of water for supplemental irrigation farmers modify and diversify the traditional cropping systems to add value to the production system. The rainfed production can be enhanced to an extent of 3 times the traditional production with improvement in agronomic practices and provision of supplemental irrigation.

Conclusion

From these experiments, it is concluded that practicing of minimum tillage and application of crop residue at 10 t ha^{-1} + supplemental drip irrigation 10 times was found to be the promising agronomic practice for enhancing growth, physiological and productivity of redgram under rainfed situation.

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