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Study on Growth and Yield Response of Redgram in Various Intercropping System and Its Economics Under Different Land Configurations in North Western Agro Climatic Zone of Tamil Nadu

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The field experiment was conducted to understand the redgram growth, yield response and economics under different land configurations and intercropping systems. The experiment was laid out in split plot design with three main factors as land configurations of compartmental bunding, broad bed Furrow and ridges and furrow and seven sub factors as redgram + blackgram (4:5), redgram + greengram (4:5), redgram + Cowpea (4:5), redgram + Groundnut (4:5), redgram + sesame (4:5), redgram + cotton (4:4) and redgram sole cropping and were replicated thrice. The higher redgram plant height, leaf area index, dry matter production, redgram grain yield and net return were recorded with ridges and furrow method of sowing. Among the intercropping systems, higher redgram plant height, leaf area index, dry matter production, redgram grain yield and net return were recorded in redgram + blackgram intercropping system. This was comparable withintercropped with redgram + groundnut (S_4), and greengram (S_2) intercropping system.

Key words: Land configuration, Intercropping, Redgram, Compartmental bunding, Ridges and furrow, Broad bed furrow

Redgram is one of the major grain legume crops of the tropical and subtropical regions. It is grown predominantly under rainfed conditions. It occupies 1.76 % of the gross cropped area and 22 % of the total pulse production in India. In India, pigeonpea ranks second in both area and production, next only to chickpea. It is grown over an area of 3.38 m ha producing nearly 2.88 m t with an average productivity of 640 kg ha^{-1} (Indiastat, 2018). It is an important constituent of the Indian diet. The pigeonpea protein compares well with that of other grain legumes. It contains 20-21 % of protein. In Tamil Nadu, redgram was cultivated in 0.056 m ha of area with the production of 0.048 m t and the average productivity was 913 kg ha^{-1} during 2016 - 2017 (India stat, 2018). In North Western Zone of Tamil Nadu, redgram is cultivated as rainfed crop. Generally, farmers take sowing after receipt of south west monsoon rainfall from June last week onwards. The field is ploughed by cultivator to form ridges and furrow. They sow two rows of redgram and four to six rows of groundnut as intercrop by manual sowing. Apart from providing biological insurance, it ensures higher total yield advantage than sole cropping of component crops due to efficient utilization of resources (Andrews, 1972). There is a more scope to improve the existing system by adopting various moisture conservation practices such as compartmental bunding, broad bed furrow and ridges and furrow and introducing various intercrops with redgram to gain more farm income by crop intensification. With this study was conducted with the objective of understanding the growth and yield responses of redgram with different intercrops under various land configurations.

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Material and Methods

The field experiment was conducted during August, 2017 to February, 2018 in Regional Research Station, Paiyur, Tamil Nadu Agricultural University at 12°21´ N and 78°18´ E, to study the different redgram based intercropping system with different land configurations under rainfed ecosystem to assess the redgram growth and yield response with varied intercrops. The soils of the experimental field is red sandy loam with pH of 6.1, organic matter content 0.32 %, total N content 198 kg ha^{-1}, total P content 16.8 kg ha^{-1}and total K content 256 kg ha^{-1}. Total rainfall received during the crop period is 812.0 mm with 62 rainy days and soil moisture availability range from 20 to 35 % during the entire growing period. The experiment was laid out in split plot design with three main factors of land configurations *viz*., compartmental bunding, L_2 - broad bed furrow and L_3 – ridges and furrow and seven sub factors as S_1- redgram + Blackgram (4:5), S_2 - redgram + Greengram (4:5), S_3 - redgram + cowpea (4:5), S_4 - redgram + groundnut (4:5), S_5 - redgram + sesame (4:5), S_6 -redgram + cotton (4:4) and S_7 -redgram sole crop and were replicated thrice. Test varieties were Co (Rg) 7, Co 6, Co 8, VBN 1, TMV 13, TMV 7 and Co 14 for redgram, blackgram, greengram, cowpea, groundnut, sesame and cotton crops respectively. After main field preparation land configurations were made manually with gross plot size of 8.6 m × 3.8 m (32.68 m^2) and net plot size of 7.8 m × .3.0 m (23.4 m^2). The compartmental bunding made by bunds around the plot to favour the infiltration of rain water without get off. In broad bed furrow, beds were formed manually with the width of 150 cm and furrow with width of 30 cm and 15 cm depth for both main and intercrops. Ridges & furrow were opened with the spacing of 45 cm for redgram and cotton and 30 cm for blackgram, greengram, cowpea, groundnut and sesame and sowing was done by dippling method with the spacing of 45 X 30 cm for redgram and cotton, 30 X 15 for cowpea and 30 X 10 for blackgram. greengram, groundnut and sesame crops. The fertilizers applied individually for both main crop and intercrop as per the blanket recommendation. All the cultural practices for respective crops under rainfed condition were followed as per TNAU crop production guide**.** After crop establishment**,** five plants at random from each plot were selected and tagged for the purpose of recording growth attributes. Plant height was recorded from the ground level to the growing tip of the main shoot at harvest stage of crop growth. The total number of green leaves, length and breadth of the third leaf from the top of the tagged plants were measured in each plot at flowering stage. The leaf area index was then worked out by using the formula as suggested by Hughes *et al*. (1979).

Plant samples for dry matter studies were collected at harvest stage. The collected samples were air dried and then oven dried at 65 ± 5^{0}C till it reached a constant weight. The total dry matter production (DMP) was expressed in kg ha^{-1}. The redgram net plot area was harvested treatment wise. After harvesting, the plants were bundled and allowed for sun drying. After complete sun drying, the crop was threshed by beating with wooden sticks. The seeds were winnowed, cleaned and dried, and seed yield per net plot was recorded and computed to kg ha^{-1}. The data were subjected to statistical scrutiny as per the procedure given by Gomez and Gomez (1984). The cost of cultivation worked out based on the inputs used and labor wages and the net return was worked out by using the formula (Net return = gross return - cost of cultivation). Wherever, the treatment differences were found as significant (F test) critical differences were worked out at 5 per cent probability level and the values were furnished in the respective tables.

Results and Discussion

Effect of land configurations and intercropping on redgram

Plant height

Among the different land configurations, ridges and furrow method of sowing recorded higher redgram plant height of 206 cm. This was on par with compartmental bunding method of sowing. Lower plant height recorded in broad bed furrow method of sowing and compartmental bunding method of sowing (Table 1), this might be due to the lower soil moisture storage than ridges and furrow method of sowing. The plant height of redgram in ridges and furrow was increased by 9.2 percent higher than compartmental bunding method of sowing and 23.0 per cent higher than broad bed furrow method of sowing. In the same way, higher plant height in ridges and furrow was reported by Deshmukh and Patel (2013) in pearl millet and Singh *et al*. (2013) in sorghum crops. This was due to maintaining the favorable moisture condition for relatively longer duration in ridges and furrow method of sowing (Parihar *et al*. 2010; Singh *et al*., 2013).

Table 1. Effect of land configurations and intercropping on redgram plant height, leaf area index and dry matter production

Treatments	Plant height (cm)				Leaf area index				Dry matter production (kg/ha)			
Intercropping	Land configuration				Land configuration				Land configuration			
	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean
S_1 – RG + BG (4:5)	195	162	216	191	3.15	2.75	3.53	3.15	1608	1401	1748	1586
S_2 – RG + GG (4:5)	187	159	207	184	2.98	2.54	3.40	2.97	1533	1305	1748	1529
S_3 – RG + CP (4:5	180	152	196	176	1.90	1.52	2.12	1.84	1264	1102	1472	1279
S_4 – RG + GN (4:5)	195	160	214	190	3.13	2.58	3.41	3.04	1662	1322	1801	1595
S_5 – RG + SM (4:5)	178	151	195	175	1.83	1.53	2.11	1.82	1153	1046	1419	1206
S_6 – RG + Cotton (4:4)	177	151	194	174	1.71	1.30	1.90	1.64	1114	981	1392	1162
S_7 – RG (Sole crop)	196	164	219	193	2.52	2.04	2.72	2.42	2152	1751	2039	1981
Mean	187	157	206		2.46	2.04	2.74		1498	1273	1660	
	L	S	L at S	S at L	L	S	L at S	S at L	L	S	L at S	S at L
SEd	10	2	10	3	0.10	0.07	0.15	0.12	78	52	115	91
CD (P = 0.05)	27	4	NS	NS	0.26	0.14	NS	NS	218	106	NS	NS

Land configurations - L_1 – Compartmental bunding; L_2 – Broad bed and Furrow (BBF); L_3 – Ridges and furrow
RG – Redgram; BG – Blackgram; GG – Greengram; CP – Cowpea; GN – Groundnut; SM - Sesame

In different intercropping, redgram pure crop recorded maximum plant height as 193 cm. This was comparable with plant height of redgram raised with blackgram and groundnut intercropping. The redgram plant height in groundnut intercropping was 7.8, 8.3 and 8.9 % higher than cowpea, sesame and cotton intercropping. These results are conformity with the findings of Shivran and Ahlawat (2000), who reported that plant height in sole redgram and redgram intercropped with blackgram, did not differ significantly due to absence of competition between the crops and it favored to increased redgram plant height. The lower plant height of redgram was recorded with intercropping of cowpea, which was on par with plant height of redgram in sesame and cotton intercropping. This was due to the taller plant height and more biomass production of cowpea, sesame and cotton (Srichandan and Mangaraj, 2015; Junejo, 2006) might have depressed the growth of associated redgram where the growth rate was usually lower during initial growth stages.

Table 2. Effect of land configurations and intercropping on absolute growth rate, crop growth rate and biomass duration of redgram at active vegetative growth to flowering stage

Treatments	Absolute growth rate (g/plant/day)				Crop growth rate (g/cm²/day)				Biomass duration (g. day)			
Intercropping	Land configuration				Land configuration				Land configuration			
	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean
S_1 – RG + BG (4:5)	0.656	0.575	0.723	0.651	4.862	4.257	5.356	4.825	1113	1013	1250	1125
S_2 – RG + GG (4:5)	0.623	0.528	0.719	0.623	4.612	3.914	5.324	4.616	1084	947	1195	1075
S_3 – RG + CP (4:5	0.471	0.418	0.565	0.485	3.488	3.098	4.188	3.592	760	668	811	746
S_4 – RG + GN (4:5)	0.679	0.535	0.740	0.652	5.033	3.966	5.485	4.828	1102	978	1177	1085
S_5 – RG + SM (4:5)	0.410	0.381	0.533	0.441	3.034	2.824	3.946	3.268	639	581	723	648
S_6 – RG + Cotton (4:4)	0.385	0.344	0.516	0.415	2.855	2.550	3.823	3.076	529	493	590	537
S_7 – RG (Sole crop)	0.343	0.257	0.304	0.301	2.542	1.905	2.249	2.232	687	615	752	685
Mean	0.510	0.434	0.586		3.775	3.216	4.339		845	756	928	
	L	S	L at S	S at L	L	S	L at S	S at L	L	S	L at S	S at L
SEd	0.028	0.021	0.044	0.036	0.206	0.155	0.323	0.269	178	137	283	237
CD (P = 0.05)	0.077	0.043	NS	NS	0.572	0.315	NS	NS	494	278	NS	NS

Land configurations - L_1 – Compartmental bunding; L_2 – Broad bed and Furrow (BBF); L_3 – Ridges and furrow

RG – Redgram; BG – Blackgram; GG – Greengram; CP – Cowpea; GN – Groundnut; SM - Sesame

Leaf area index

Higher leaf area index of redgram (2.74) was observed in ridges and furrow method of sowing. This was followed by redgram leaf area index (2.46) in compartmental bunding. The lowest leaf area index of redgram (2.04) was recorded in broad bed furrow sowing (Table 1). The similar findings was reported by Ambika *et al*. (2017) in cotton, this might be due to higher production of number of leaves with more number of branches (Kumar *et al*., 2003) and also due to maintenance of proper air moisture regimes under ridges and furrow sowing which in turn resulting in good supply of required moisture, available nutrients, soil aeration, soil environment and better growth and development (Deshmukh and Patel, 2013).

Among the intercropping, higher redgram leaf area index (3.15) was recorded in blackgram intercropping. This was on par with redgram leaf area index grown with groundnut intercropping. Followed by higher redgram leaf area index was recorded in redgram pure crop and cowpea intercropping, which were on par with leaf area index of redgram in sesame intercropping. Lower leaf area index of redgram (1.64) was recorded in cotton (S_6) intercropping (Table 1). Increased leaf area index of redgram intercropped with blackgram, greengram and groundnut was might be the absence of competition and wider space availability in between the every four rows of redgram leads maximum foliage development and dry matter production by extending their branches. This factor facilitated to produce maximum number of leaves and leaf area index (Nejad, 2011). These results were close relation with findings of Shivran and Ahlawat (2000).

Dry matter production

Higher dry matter production of 1660 kg ha^{-1} was recorded in ridges and furrow method of sowing (Table 1). This was on par with compartmental bunding method of sowing. This increased DMP was 9.7 % higher than compartmental bunding method of sowing and 23.3 % higher than broad bed furrow method of sowing. This might be due to the conservation of rain water and its availability for longer duration, mini barriers in run-off of water and increased moisture probably improved the availability of nutrients as well as nutrient uptake (Bhople *et al*., 2018) which in turn might have helped to enhance physiological process. This in turn increased the vertical and lateral growth leading to higher dry matter accumulation (Nejad, 2011). The lower redgram dry matter production of 1273 kg ha^{-1} was recorded with broad bed furrow method of sowing. The similar findings were reported by Deshmukh and Patel (2013), Karimvand *et al*. (2013), Ambika *et al*. (2017) and Bhople *et al*. (2018) in cluster bean, sorghum, pearlmillet, cowpea, cotton and sunflower, respectively.

In different inter cropping system, redgram pure crop recorded the highest dry matter production of 1981 kg ha^{-1}. Next to this, higher redgram dry matter production of 1595 kg ha^{-1} was recorded with groundnut intercropping (Table 1). This was on par with redgram dry matter production in blackgram (S_1) and greengram (S_2) intercropping. DMP increased by 19.8, 24.3 and 27.1 % higher than cowpea, sesame and cotton intercropping, This might be due to the absence of competition between redgram and intercrops of blackgram, greengram and groundnut which lead to maximum DMP by enhanced crop growth rate (Srichandan and Mangaraj, 2015). The lower redgram dry matter production recorded with cowpea sesame and cotton (1162 kg ha^{-1}) intercropping (Table 1). This was confirmed with the findings of Soniya (2014) in redgram.

Table 3. Effect of land configurations and intercropping on redgram grain yield, cost of cultivation and net returns

Treatments	Grain yield (kg/ha)				Cost of cultivation (Rs.)				Net return (Rs.)			
Intercropping	Land configuration				Land configuration				Land configuration			
	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean
S_1 - RG + BG (4:5)	562 (466)	491 (440)	611 (528)	555 (478)	22153	23953	25753	23953	39305	31422	42162	37630
S_2 - RG + GG (4:5)	532 (460)	453 (431)	607 (521)	531 (471)	22013	23803	25593	23803	38112	29503	42692	36769
S_3 - RG + CP (4:5	420 (417)	362 (395)	491 (453)	424 (421)	22193	24017	25815	24008	20558	14167	22953	19226
S_4 – RG + GN (4:5)	581 (1002)	461 (846)	630 (928)	557 (925)	26253	28066	29841	28053	38394	24596	36078	33023
S_5 – RG + SM (4:5)	383 (382)	344 (366)	473 (435)	400 (394)	21654	23466	25278	23466	33080	27471	39555	33369
S_6 – RG + Cotton (4:4)	367 (441)	326 (387)	449 (527)	381 (452)	22008	23791	25408	23736	24663	17384	31112	24387
S_7 – RG (Sole crop)	747	608	788	714	22483	24290	26083	24285	26827	15855	25888	22857
Mean	513 (453)	435 (409)	578 (485)		22679	24484	26253		31563	22914	34349	
	L	S	L at S	S at L	L	S	L at S	S at L	L	S	L at S	S at L
SEd	27	18	39	31	-	-	-	-	2387	1464	3348	2535
CD (P = 0.05)	74	36	NS	NS	-	-	-	-	6629	2968	NS	NS

Land configurations - L_1 – Compartmental bunding; L_2 – Broad bed and Furrow (BBF); L_3 – Ridges and furrow
RG – Redgram; BG – Blackgram; GG – Greengram; CP – Cowpea; GN – Groundnut; SM - Sesame
*In parenthesis, intercrops yield given; * Cost of cultivation not analyzed by statistical tool

Absolute growth rate, Crop growth rate and biomass duration

Active *vegetative growth to flowering stage*

The ridges and furrow (L_3) method recorded higher absolute growth, crop growth rate and biomass duration of 0.586 g/plant/day, 4.33 g/cm²/day and 1118 g. day respectively (Table 2). This was on par with compartmental bunding method of sowing. This was might be the optimum soil moisture availability throughout the growing period of redgram, which might be enhanced the process of cell division, elongation for every incremental increase in crop growth by increased photosynthesis (Parihar *et al.* 2010). Followed by the lower redgram absolute growth, crop growth rate and biomass duration of 0.434 g/plant/day, 3.216 g/cm²/day and 1173 g. day was recorded with broad bed furrow method of sowing.

Table 4. Correlation between growth parameters and grain yield of redgram

	Plant height	LAI	Dry matter production	Absolute growth rate	Crop growth rate	Biomass duration	Grain yield
Plant height	1						
Leaf area index	0.830322	1					
Dry matter production	0.928601	0.630621	1				
Absolute growth rate	0.257	0.724081	-0.05877	1			
Crop growth rate	0.25734	0.724427	-0.0585	0.999999	1		
Biomass duration	0.628917	0.942054	0.380739	0.894953	0.895112	1	
Grain yield	0.931055	0.635755	0.999856	-0.05493	-0.05464	0.384082	1

In different inter cropping system, higher redgram absolute growth, crop growth rate and biomass duration of 0.652 g plant-1 day-1, 4.828 g cm-2day-1 and 1173 g. day (Table 2) respectively was recorded with groundnut intercropping system. This was on par with redgram absolute growth, crop growth rate and biomass duration of redgram in blackgram and greengram intercropping. This was followed by lower redgram absolute growth, crop growth rate and biomass duration with cowpea and sesame intercropping. These were on par with redgram absolute growth, crop growth rate and biomass duration of redgram raised with cotton intercropping and the lowest absolute growth, crop growth rate and biomass duration was recorded in redgram pure crop. This might be the reason of competition between redgram in sole crop for light interception, nutrient and moisture. But, intercropping with short duration and shorter legume crops shows anidation effect with redgram by wider space availability between the each four rows of redgram and results increased growth of redgram in border rows by receiving more light and high soil moisture and nutrients without any competition and attained more growth rate (Verdelli et al., 2012).

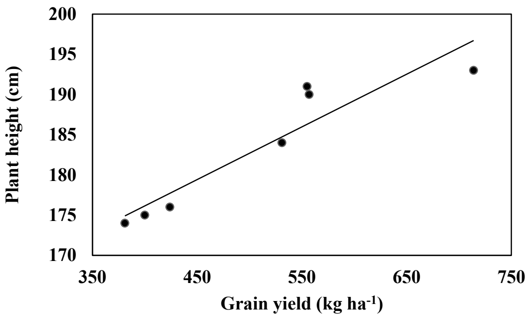

Fig. 1. Correlation between plant height and grain yield of redgram

Grain yield

Among the different land configurations, sowing in ridges and furrow method recorded higher redgram grain yield of 578 kg ha^{-1}. This was on par with grain yield of redgram (513 kg ha^{-1}) in compartmental bunding method of sowing. The lowest redgram grain yield of 435 kg ha^{-1} was recorded with broad bed furrow method of sowing (Table 3.). This result was in line with the findings of Hadvani *et al*. (1993). Similarly, Somasundaram *et al,* (2000), reported yield advantage in sorghum, cowpea, bengalgram and sunflower under ridges and furrow. Redgram grain yield obtained in ridges and furrow method increased by 11.2 % higher than compartmental bunding and 24.7 % higher than broad bed furrow sowing method.

Among the different intercropping system, maximum redgram grain yield of 714 kg ha^{-1} was recorded in redgram pure crop. Next to this higher redgram grain yield was recorded in redgram raised with groundnut, blackgram and greengram inter cropping (Table 3.). These were on par with each other. The redgram grain yield in redgram + groundnut intercropping system was increased 23.8, 28.1 and 31.0 % higher than cowpea, sesame and cotton intercropping. This might be due to the no competition between the intercrops, which enhanced the yield of both component crops. Similarly, Prakash and Bhushan (2000) also, reported that while pigeonpea was intercropped with greengram, gave higher in productivity and profitability in rainfed alfisols. The lower redgram grain yield was recorded with cowpea, sesame and cotton intercropping. This might be the sharing of resources with redgram and offered competition thereby reducing the optimum growth and development of redgram was the reason for low grain yield recorded per plant and ultimately per unit area (Soniya, 2014).

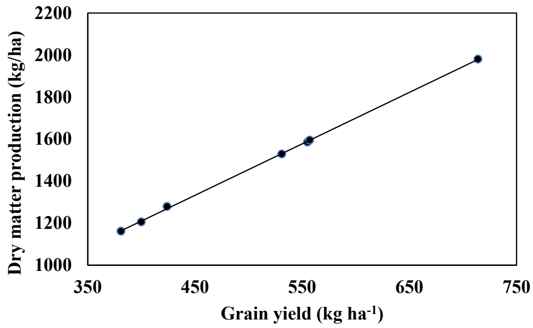

Fig. 2. Correlation between dry matter production and grain yield of redgram

Cost of cultivation and net return

Sowing in ridges and furrow method recorded the highest net return of Rs. 34349. The lower net return was recorded in compartmental bunding and broad bed furrow method of sowing (Table 3). Even though ridges and furrow required highest cultivation cost, which yearned highest net return. This was might be due to optimum soil moisture availability in ridges and furrow sowing method, it lead to increase in main crop and intercrop yield by maximum crop growth and development. Similarly, Singh *et al*. (2013) reported that ridge and furrow practice recorded 11.44 and 11.86 % increase in net returns over compartmental bunds. This might be due to higher yields of crop gained from ridges and furrow treatment. Among the various intercropping system, cost of cultivation was higher for redgram + groundnut intercropping and lower for sesame cultivation. The maximum net return of Rs. 37630 was recorded in redgram raised with blackgram intercropping system (Table 3). This was comparable with net return recorded in redgram with groundnut and greengram intercropping. This might be the reason of zero competition between redgram and intercrop, which lead to higher yield and earned net return. The lowest net return of Rs.19226 was recorded with redgram grown in cowpea intercropping. Similar findings were reported by Prakash and Bhushan (2000) in pigeonpea + groundnut.

Correlation between growth parameters and grain yield

Grain yield shows direct relationship with dry matter production (0.99), plant height (0.93), leaf area index (0.63) and biomass duration (0.38). At the same time absolute growth rate, crop growth rate shows negative relationship with grain yield of redgram. This might be the reason of fluctuation of growth rate by day to day, but plant height and dry matter productions were determined as standard at harvest stage (Table 4). This ensures that, plant height and dry matter production strongly influence the redgram grain yield (Fig. 1 & 2) than other growth attributes.

Dry matter production shows higher correlation with plant height (0.92) and biomass duration expressed higher correlation with leaf area index, absolute growth rate, crop growth rate with the value of 0.94, 0.89 and 0.89 respectively. In this research, the positive and significant correlation was observed between grain yield and other growth attributes except absolute growth rate and crop growth rate, similar findings, also reported by Mohammadi *et al*. (2012).

Conclusion

From this experiment, it can be concluded that, For North Western Zone of Tamil Nadu, redgram intercropping with groundnut, blackgram and greengram with 4:5 ratio recorded higher grain yield of redgram in addition to intercrop yield achieve higher net return than other intercropping system and sole redgram. Among the different land configurations, ridges and furrow method of sowing recorded higher redgram growth and grain yield.

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