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Full Length Article

Relative Performance of Groundnut (*Arachis hypogaea*) based Intercropping Systems under Different Irrigation Levels

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Abstract

The suitability of intercropping system relies on the appropriate selection of companion crop and adequate irrigation application for both crops to sustain and bloom. In this regard, this two-year field study was conducted to evaluate the performance of groundnut based intercropping systems with different irrigation levels on growth, yield, consumptive use, water use efficiency and light interception of groundnut. The intercropping systems included in the study were: sole groundnut, groundnut + castor, groundnut + blackgram, groundnut + sesame and groundnut + pearl millet. Irrigations scheduled as IW/CPE ratio of 0.50, 0.75 and 1.0 were assigned. Groundnut + blackgram and sole groundnut at IW/CPE 0.75 realized highest equivalent yield (2274 kg ha^{-1}) and water use efficiency (4.85 kg ha^{-1} mm^{-1}). While, lowest equivalent yields were recorded in groundnut + pearl millet system at irrigation regime IW/CPE 0.50 (1413 kg ha^{-1}). Similarly, higher consumptive water use was noticed under groundnut + pearl millet with highest at IW/CPE 1.0 irrigation regime. Higher mean light interception under groundnut + castor varied from 38.4% to 39.9% causing more shading effect on groundnut. Competitive and bio-economic indices indicated in favor of groundnut + blackgram under irrigation regime IW/CPE 0.75. The same system realized higher net income of 1238.60 $ ha^{-1} with benefit: cost ratio of 3.00 over other treatments. Hence, groundnut + blackgram intercropping system periodically irrigated at IW/CPE 0.75 could enhance the productivity and profitability of the system. © 2019 Friends Science Publishers

Keywords: Groundnut intercropping; Irrigation scheduling; Consumptive water use; Water use efficiency; Light interception

Introduction

Groundnut (*Arachis hypogaea* L.), an annual legume, belongs to the family Fabaceae originated from South America. It is one of the principal food and oilseed crop with excellent source of vegetable protein to both man and animal. India ranks first in the world in area (26.67 million hectares) and production (30.06 million tonnes) of oilseeds but the same is not seen in terms of edible oil production (NMOOP, 2018). Groundnut predominantly grown under tropical and sub-tropical conditions in the world is a risky crop under dryland conditions (Murungweni *et al.*, 2016). Its productivity is largely determined on the availability of rainfall received during flowering, gynophore formation and initial pod development stages (Parmar *et al.*, 2007). Aberrant weather conditions have led to an imbalance in the edible oil production due to decreased productivity. This has led to economic losses to the farmers due to the partial or total failure of groundnut crop discouraging the farmers from further cultivation. This shortage of oilseeds along with pulses has also aggravated malnutrition. Moreover, rapid industrialization and urbanization has decreased the potential of increasing the area under oilseed and pulse crops. Therefore, introduction of groundnut in intercropping system offers a better scope for maximizing and stabilizing the return from oilseed crops rather than as sole (Shalim uddin *et al.*, 2003).

Crop diversification could be adopted as a strategy in employment generation throughout the year and also maximizing the profit through reaping the gains by equating the substitution and price ratios for competitive products (Deshpande *et al.*, 2007). Crop compatibility is the most essential factor for a practicable intercropping system and the yield advantage under intercropping system depends on the appropriate selection of companion crop where, competition between them for solar radiation, CO_2, nutrients, moisture, spaces *etc*., is minimized (Natarajan and Willey, 1986).

Study conducted by Chaudhari *et al.* (2017) recorded higher productivity in terms of groundnut pod equivalent yield (GPEY) under groundnut + pigeon pea (*Cajanus cajan*) with 1802 kg ha^{-1} followed by groundnut + castor (*Ricinus communis*) with 1794 kg ha^{-1} and groundnut + cotton (*Gossypium hirsutum*) with 1766 kg ha^{-1} which were on par with each other and recorded significantly higher

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GPEY as compared to sole groundnut (1489 kg ha^{-1}). While significantly lowest GPEY recorded in groundnut + pearl millet (991 kg ha^{-1}), groundnut + soybean (1186 kg ha^{-1}) and black gram (1241 kg ha^{-1}) compared to sole groundnut mainly due to low yield of component crops and lower market price of intercrops. Similar study conducted by Bhuva *et al.* (2017) revealed that groundnut intercropped with sesame (*Sesamum indicum*) resulted higher yield and net returns over groundnut intercropped with greengram (*Vigna radiata*), mothbean (*Vigna aconitifolia*) and sole crop of groundnut. Overall higher system productivity and net income of groundnut based intercropping systems over sole crop of groundnut is well reported (Chandrika *et al*., 2001; Honnali and Chittapur, 2014).

Water is one of the crucial inputs in farming and its availability is tending to become increasingly scarce and costlier due to increased industrialization, intensive agriculture and climate changes (Hussain *et al*., 2018). Therefore, adoptions of agronomic techniques leading to higher water use efficiency (WUE) are direly needed (Farooq *et al*., 2019). Increased WUE of groundnut can be possible through optimum application of irrigation by providing the water that match the crop evapotranspiration and at critical growth stages (Ibrahim *et al.*, 2002). In irrigation scheduling based on climatological approach using IW/CPE ratio (IW – irrigation water, CPE – cumulative pan evaporation) integrates all the weather parameters that determine the crop water use paving way to increase the production by at least 15–20% (Dastane, 1972).

Groundnut irrigated at IW/CPE 0.80 improved the yield attributes, pod yield, quality and improved uptake of nutrients (Patel *et al.*, 2009) Similarly, increased crop WUE and field WUE of 46.7 and 33.8 kg ha^{-1} mm^{-1} under IW/CPE 0.78 was recorded by Taha and Gullati (2001). Singh *et al.* (2018) recorded significantly higher seed yield of frenchbean (*Phaseolus vulgaris*) intercropped with blackgram irrigated based on IW/CPE 0.60 was at par with IW/CPE 0.80 irrigation regime. Khafi *et al.* (2011) reported that scheduling irrigation for pearl millet at IW/CPE 1.0 ratio yielded higher grain and fodder yield; however, fodder yield was at par with IW/CPE 0.75.

Different crops used in intercropping system need different amount of water and optimization of irrigation for all crops is needed. Therefore, this two-year field study was designed to explore the production potential and bio-economics of groundnut based intercropping system and to identify an appropriate irrigation schedule with increased WUE.

Materials and Methods

Experimental Site

The field experiment was conducted at Oilseeds Research Station (12º21 N, 79º66´E, and 45.6 m above sea-level), Tindivanam, Tamil Nadu, India for two consecutive years. The daily recorded weather data during the season of 2017 and 2018 are presented in the Table 1.

The soil samples collected from different locations in the experimental site were mixed using quarter method and analyzed for both the years (2017 and 2018). The soil sample collected was sandy loam (20.4 and 20.0% course sand, 30.6 and 30.7% fine sand, 26.2 and 26.3% silt and 22.6 and 22.8% clay) medium in organic carbon (0.56 and 0.55%), low in available nitrogen (123 and 127 mg kg^{-1}), medium in phosphorus (12.05 and 12.45 mg kg^{-1}) and potassium (102 and 99.1 mg kg^{-1}), respectively for both the consecutive years.

Experiment Materials and Design

Groundnut variety TMV 13 was used with intercrop varieties TMV 5 (castor), VBN 8 (blackgram), TMV 7 (sesame) and CO10 (pearl millet).The experiment was laid out in split plot design with 5 treatments in the main plot *viz.*, i) C_1 - sole groundnut, ii) C_2 - six rows of groundnut + one row of castor (6:1) iii) C_3 - six rows of groundnut + one row of blackgram (6:1), iv) C_4 - four rows of groundnut + one row of sesame (4:1) and v) C_5 - four rows of groundnut + one row of pearl millet (4:1). Sub plot consisted of 3 treatments based on climatological irrigation scheduling i) I_1 - IW/CPE ratio 0.50, ii) I_2 - IW/CPE ratio 0.75 and iii) I_3 - IW/CPE ratio 1.0. During both the years, all the crops were sown under replacement series with row spacing of 30 cm as per the row ratios with net plot size of 6.0 m × 4.5 m. Groundnut and blackgram with plant to plant spacing of 10 cm, castor and sesame with plant to plant spacing of 30 cm and pearl millet with plant to plant spacing of 15 cm were sown on 27th and 26th June 2017 and 2018 respectively. The row ratios used were commonly practiced and were the recommendation from the station in which the research was conducted.

Sole crop of groundnut was sown with a seed rate of 120 kg ha^{-1}, castor with 10 kg ha^{-1}, blackgram with 20 kg ha^{-1}, sesame with 5 kg ha^{-1} and pearl millet with 5 kg ha^{-1}. Seed rate for groundnut in 6 rows was kept 103 kg $ha^{-1}$and under 4 rows with 96 kg ha^{-1}. Similarly, seed rate for intercrop castor was kept 1.43 kg ha^{-1}, blackgram 2.86 kg ha^{-1}, sesame and pearl millet at 1 kg ha^{-1}. Recommended fertilizer for groundnut 25:50:75 kg nitrogen, phosphorus and potassium were applied as common for all the intercrops. Half dose of nitrogen and potassium along with full dose of phosphorus was applied as basal while the remaining dose was along with gypsum (400 kg ha^{-1}) was applied to all the treatments at 45 days after sowing. The first two irrigations were provided on the day of sowing followed by 5 to 7 days after sowing as life irrigation for better germination. The remaining irrigations of 50 mm depth were applied as per treatment based on IW/CPE ratio using daily evaporation data. Well water was the source for all the irrigation supplied to the crop. Irrigation was applied to the crops based on the cumulative pan evaporation for different irrigation regimes. All rainfall within the water holding capacity was accounted and next irrigation was calculated. To quantify the amount of water entering the experimental plot an 18-inch cut throat flume was used. During all the irrigations, the H_a and H_b depths were noted and irrigation was supplied once it became constant and the time was noted using a stop watch. Buffer channels were provided around each experimental plot to prevent the irrigation water from entering the adjacent treatment plot. The soil moisture was determined using gravimetric method. The soil samples were collected using a screw auger at the depth of 0–15 cm, 15–30 cm, 30–45 cm, 45–60 cm and 60–75 cm to determine the total consumptive use and soil moisture extraction pattern of the crop. Weeds were regularly controlled using hand hoe to avoid evapotranspiration losses. The field was regularly checked for pest and diseases and timely appropriate measures were taken. All the crops were manually harvested as they attained harvest maturity and groundnut was harvested on 8th October of 2017 and 2018, respectively.

Data Collection

The harvested groundnut crops from the respective net plots were uprooted by hand as they reached physiological maturity and the pods were stripped off manually and sun dried. The sun dried pods were cleaned and weighed using electronic weighing balance. Intercrops were also harvested manually, threshed and sun dried as they attained physiological maturity for blackgram on 65th day after sowing (DAS), sesame on 87th DAS, pearl millet on 90th DAS and Castor with first picking starting from 105th DAS. The yield of the crops was converted into kg ha^{-1}. Intercrop yield were converted into Crop Equivalent Yield (CEY) of groundnut based on price of the produce using the formula suggested by Verma and Modgel (1983):

$$CEY = \frac{Y_{ba} \times P_b}{P_a} + Y_{ab}$$

Where, Y_{ba} = Yield of ‘b’ intercropped with ‘a’; Y_{ab} = Yield of crop ‘a’ intercropped with ‘b’; P_a = Price of main crop ‘a’; P_b = Price of inter crop ‘b’ and expressed as kg ha^{-1}. Land Equivalent Ratio (LER) was calculated using the formula of Willey (1979):

$$LER = La + Lb = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

Where, La and Lb = the LERs for individual crops in the mixture; Y_{aa} and Y_{bb} = the yield of species ‘a’ and ‘b’ sole crops. LER more than 1 indicates yield advantage, while lesser than 1 indicates yield loss. Intercropping system laid in replacement series was checked for the Relative Crowding Coefficient (K_{ab}) which indicates whether a species or crop, when grown in mixed population, has produced more or less yield than expected in pure stand (Wit, 1960):

$$K_{ab} = \frac{Y_{ab} \times Z_{ba}}{(Y_{aa} - Y_{ab}) \times Z_{ab}}$$

Where, K_{ab} is the relative crowding coefficient of groundnut. Z_{ab} = Sown proportion of ‘a’ in combination with ‘b’; Z_{ba} = Sown proportion of ‘b’ in combination with ‘a’. Aggressivity was calculated by the formula proposed by McGilchrist (1965) to estimate the interspecies competitiveness of intercrops over groundnut in the system:

$$A_{ab} = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} - \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

Where, A_{ab} is the aggressivity of groundnut in relation to the other intercrops. If the value is zero indicates that the component crops are equally competitive while the sign for the dominant component will be positive and that of the dominated negative.

Relative Production Efficiency (RPE) refers to the potentiality of the new system in comparison to the existing system and expressed in percentage using the formula suggested by Urkurkar *et al.* (2008):

$$RPE = \frac{(EYD - EYE)}{EYE} \times 100$$

Where, EYD = Equivalent yield under improved system; EYE = Existing system yield; Positive RPE denotes superiority of the new system and negative denote lesser desirability for change.

Water Use Efficiency

Water use efficiency (WUE) is the total yield produced from the unit consumptive use of water using the following formula:

$$WUE = \frac{\text{Equivalent yield (kg ha}^{-1}\text{)}}{\text{Total consumptive use (mm)}}$$

Where, total consumptive use (mm) is the total moisture depleted from the soil at different intervals + soil moisture contribution + effective rainfall. The soil moisture depletion was calculated using the formula suggested by Dastane (1972):

$$d = \sum_{i=1}^{n} \frac{M_1^i - M_2^i}{100} \times AS^i \times D^i \times ER$$

Where, d = moisture deficit in the root zone; M_1^i = Soil moisture in the ith layer of profile 24 h after irrigation; M_2^i = Soil moisture in the ith layer of profile 24 h before the next irrigation; AS^i= Bulk density of the ith layer (g cc^{-1}); D^i= Depth of the ith layer (cm); ER= Effective Rainfall.

Light Interception

Light interception (LI) was calculated using light intensity recorded on 30 DAS, 60 DAS and 90 DAS using a lux meter at different time intervals at 10:00 A.M., 12:00 P.M. and 2:00 P.M. At each time the values were noted at the top, middle and ground level of the crop. For each time interval, the mean value for the particular day was arrived and the light interception was calculated keeping the light intensity in the open as constant. Similar method of estimation done by Rosenthal and Gerik (1991) and Kiniry *et al.* (2004) using the formula:

$$LI\ (\%) = \frac{(L_o - L_c)}{L_o} \times 100$$

Where, LI = Light interception, L_o = Light intensity in the open, L_c= Average light intensity of the crop.

Economic Analysis

The collected data for both years were economically examined by using standard methods formulated by CIMMYT (1988). For each intercropping system, partial budgeting was calculated to determine the expenses incurred and net returns. In the investigation, the present prices of inputs prevailing in the market during 2016–2017 and 2017–2018 were used to calculate the partial budget of different intercropping systems.

Statistical Analysis

Analysis of variance (ANOVA) was performed with the S.A.S./STAT software (S.A.S. Institute, 1999). The analysis of the data for the years was done separately and the homogeneity of variances was tested using the Bartlett's Chi-square test. The data with heterogeneous variances were applied with Aitken's square root transformation. The combined analysis was done using the PROC GLM procedure considering the years as fixed effects. Critical difference (CD) at 5% level of probability and P values were used to examine differences among the treatment means.

Results

Groundnut Yield and Equivalent Yield

Analysis of pooled data indicated that interaction between intercropping systems and irrigation regimes had significant effect on grain yield and equivalent yield of groundnut (Table 2). In terms of equivalent yield groundnut + blackgram intercropping and sole crop of groundnut at IW/CPE 0.75 irrigation regime observed higher while, groundnut + pearl millet intercropping recorded the lowest equivalent yield of groundnut compared with all other combinations. Secondly, groundnut + blackgram intercropping was found comparable with sole groundnut at IW/CPE 1.0 indicating higher yields under groundnut + blackgram system irrespective of irrigation regimes. On the other hand, groundnut + castor and groundnut + sesame also recorded lower yields over the sole crop of groundnut.

Consumptive Water use

From the pooled data, consumptive water use revealed significant correlation to the water requirement of different crops in intercropping system to the number of irrigation applied to the crop (Table 2). Groundnut + pearl millet at IW/CPE 1.0 recorded highest consumptive water use (591 mm) along with groundnut + castor (585 mm) and groundnut + sesame (579 mm) while sole groundnut under the same irrigation regime recorded 565 mm. While, lowest amount of water from the soil was taken up by groundnut + blackgram (462 mm) and sole groundnut (469 mm) under IW/CPE 0.50. The varying interaction data could be attributed to the total biological yield, water requirement and number of irrigations supplied to both the crops in the intercropping system.

Water use Efficiency

Pooled data revealed significant increase in WUE of groundnut + blackgram with 4.85 kg ha^{-1} mm^{-1} (equivalent to 48.5 g per litre of water) followed by sole groundnut (4.53 kg ha^{-1} mm^{-1}) at IW/CPE 0.75 (Table 3). Furthermore, groundnut + blackgram under IW/CPE 0.50 (3.99 kg ha^{-1} mm^{-1}) and IW/CPE 1.0 (3.79 kg ha^{-1} mm^{-1}) along with sole groundnut at IW/CPE 1.0 recorded higher WUE. While, least efficient water use was noted in groundnut + pearl millet at IW/CPE 1.0 (2.88 kg ha^{-1} mm^{-1}) and IW/CPE 0.50 (2.92 kg ha^{-1} mm^{-1}) as a result of lesser yield with higher consumptive water use from the system.

Light Interception

Pooled data of interaction on the light interception on groundnut under intercropping system and irrigation regimes was not significant but, ranged from 23.2% to 39.9%, indicating the occurrence of shading effect from the associate crop (Table 3). Highest mean light interception of groundnut was noticed under groundnut + castor system followed by groundnut + pearl millet. Further, groundnut intercropped with pearl millet had higher interception at earlier stages but overall lower in comparison to the groundnut + castor due to higher duration of castor. Lower light interception was noted under groundnut + blackgram system. The rate of light interception on groundnut was directly proportional to the growth rates of intercrop as well as the row ratios in which crops were planted. As a result, higher light interception was noted under irrigation regime IW/CPE 0.75.

Competition and Biological Indices

Relative crowding coefficient: Relative crowding coefficient (RCC) played a significant role in determining

Table 1: Meteorological data of the experimental site at different stages of groundnut

Year	Month	Temperature (ºC)			RH(%)	Rainfall (mm)	PE (mm day^{-1})	Wind speed (km h^{-1})	Solar radiation (cal cm^{-2})
		Max	Min	Mean					
2017	June	36.4	25.5	31.0	70.8	0.00	5.44	5.59	375.7
	July	33.6	24.5	29.0	81.0	0.00	5.69	2.43	465.0
	August	33.3	25.7	29.4	77.9	0.00	5.99	2.23	475.7
	September	31.0	25.1	28.1	82.5	50.0	5.84	1.73	454.1
	October	28.8	24.2	26.5	81.3	351.5	4.58	1.73	426.7
2018	June	37.8	27.7	32.8	70.0	168.2	5.33	3.53	377.4
	July	36.5	27.1	31.8	70.1	64.3	6.95	3.71	378.2
	August	35.4	25.5	30.4	72.5	203.8	6.34	3.34	373.7
	September	34.7	25.4	30.1	75.3	390.5	6.45	2.52	494.3
	October	32.5	24.3	28.4	75.6	462.9	6.00	1.69	467.3

Max=Maximum, Min=Minimum, RH=Relative Humidity, PE=Pan Evaporation per day. Data was recorded in the meteorology observatory (Meteorological observatory; Automatic Weather Station) present in the Oilseeds Research Station, Tamil Nadu, India

Table 2: Effect of intercropping system and irrigation scheduling on the Grain yield, Equivalent yield and Consumptive water use of groundnut (Pooled data of 2017 and 2018)

Treatment	Grain yield (kg ha^{-1})			Equivalent yield (kg ha^{-1})			Consumptive water use (mm)		
	I_1	I_2	I_3	I_1	I_2	I_3	I_1	I_2	I_3
C_1	1775^{c}	2170^{a}	2045^{ab}	1775^{gh}	2170^{ab}	2045^{cd}	469^{ef}	479^{cdef}	565^{b}
C_2	1357^{f}	1746^{c}	1651^{cd}	1508^{ij}	1916^{ef}	1812^{fgh}	480^{cdef}	496^{cd}	585^{a}
C_3	1669^{cd}	2071^{ab}	1934^{b}	1843^{fg}	2274^{a}	2124^{bc}	462^{f}	469^{ef}	561^{b}
C_4	1336^{f}	1701^{cd}	1587d^{e}	1580^{i}	1987de	1855^{fg}	473^{def}	485^{cdef}	579^{ab}
C_5	1123^{g}	1480^{ef}	1365^{f}	1413^{j}	1838^{fg}	1704^{h}	484^{cdef}	498^{c}	591^{a}
LSD @ 5%	153			122			23.9		

Cropping system C_1-Sole groundnut; C_2-Groudnut + Castor; C_3-Groudnut + Blackgram; C_4-Grondnut + Sesame; C_5-Groundnut + Pearl millet; Irrigation Scheduling I_1- IW/CPE 0.50; I_2- IW/CPE 0.75; I_3- IW/CPE 1.0

Table 3: Effect of intercropping system and irrigation scheduling on the Water use efficiency and Mean light interception of groundnut (Pooled data of 2017 and 2018)

Treatment	Water use efficiency (kg ha^{-1} mm^{-1})			Mean light interception (%)		
	I_1	I_2	I_3	I_1	I_2	I_3
C_1	3.79^{d}	4.53^{b}	3.62^{de}	23.8	25.6	24.5
C_2	3.14^{e}	3.87^{cd}	3.10^{e}	38.4	39.9	38.9
C_3	3.99^{c}	4.85^{a}	3.79^{d}	23.2	25.0	23.8
C_4	3.34^{e}	4.10^{c}	3.20^{ef}	28.0	29.8	28.7
C_5	2.92^{f}	3.69^{d}	2.88^{g}	34.2	35.7	34.7
LSD value at 5%		0.29			NS	

Cropping system C_1-Sole groundnut; C_2-Groudnut + Castor; C_3-Groudnut + Blackgram; C_4-Grondnut + Sesame; C_5-Groundnut + Pearl millet; Irrigation Scheduling I_1- IW/CPE 0.50; I_2- IW/CPE 0.75; I_3- IW/CPE 1.0; NS = Non-significant

the competition effects under intercropping system. The product of RCC greater than 1 indicates the advantage of the intercropping over the sole cropping system. Reviewing the pooled data of interaction, groundnut + blackgram noted significantly higher RCC of groundnut (3.47) and system (3.84) at irrigation regime IW/CPE 0.75 followed by IW/CPE 1.0 and IW/CPE 0.50 resulting advantageous over other intercropping systems (Table 4). Secondly, groundnut + sesame irrespective of irrigation regimes ended comparatively lesser and was followed by castor indicating a definite yield loss from the system. Further, the lowest RCC values were recorded in groundnut + pearl millet at irrigation scheduling IW/CPE 0.50 and 1.0 exhibited that the intercrop pearl millet utilized resources more competitively than groundnut.

Aggressivity

The pooled data of interaction on aggressivity for groundnut observed negative values of groundnut intercropped with pearl millet, castor and sesame intercropping system (Table 6). This (-) sign indicates that the component crop resulted more dominant over groundnut. Mutually benefiting nature was noted in groundnut + blackgram at irrigation regime IW/CPE 0.75 followed by IW/CPE 1.0 while, higher competition for natural resources was under groundnut + pearl millet and groundnut + castor under IW/CPE 0.50 indicating significantly greater difference in the competitive ability between the component crop, resulting in wide variations between the actual and expected yields. Further, it was examined that irrigation scheduling IW/CPE 1.0 was more dominant than IW/CPE 0.75.

Land Equivalent Ratio

Land equivalent ratio (LER) showed significant interaction between intercropping system and irrigation regimes. Groundnut + blackgram intercropping system resulted in

Table 4: Effect of intercropping system and irrigation scheduling on the competitive indices of groundnut intercropping system (Pooled data of 2017 and 2018)

Treatment	Relative crowding coefficient			Aggressivity		
	I_1	I_2	I_3	I_1	I_2	I_3
C_2	0.54^{ef} (0.72)	0.69^{de} (0.94)	0.70^{de} (0.95)	-0.386^{cd}	-0.340^{c}	-0.341^{c}
C_3	2.67^{b} (2.75)	3.47^{a} (3.84)	2.94^{b} (3.17)	0.001^{a}	0.025^{a}	0.018^{a}
C_4	0.76^{cd} (0.82)	0.91^{c} (1.06)	0.86^{cd} (0.98)	-0.124^{b}	-0.107^{b}	-0.120^{b}
C_5	0.43^{f} (0.58)	0.54^{ef} (0.69)	0.50^{f} (0.65)	-0.436^{d}	-0.348^{cd}	-0.383^{cd}
LSD @ 5%		0.17			0.090	

Treatments comprising sole groundnut was omitted

Values in parenthesis are the product of Groundnut and Intercrop Relative Crowding Coefficient

Cropping system C_1-Groudnut + Castor; C_3-Groundut + Blackgram; C_4-Grondnut + Sesame; C_5-Groundnut + Pearl millet; Irrigation Scheduling I_1- IW/CPE 0.50; I_2- IW/CPE 0.75; I_3- IW/CPE 1.0

Table 5: Effect of intercropping system and irrigation scheduling on the bio-economical indices of groundnut intercropping system (Pooled data of 2017 and 2018)

Treatment	Land equivalent ratio			Relative production efficiency		
	I_1	I_2	I_3	I_1	I_2	I_3
C_2	0.950^{f}	0.990^{d}	0.995^{d}	-13.5^{d}	-10.3^{c}	-9.95^{c}
C_3	1.090^{b}	1.110^{a}	1.100^{ab}	3.81^{a}	4.74^{a}	3.82^{a}
C_4	0.965^{e}	1.010^{c}	0.995^{d}	-11.1^{c}	-8.44^{b}	-9.38^{bc}
C_5	0.885^{h}	0.925^{g}	0.915^{g}	-20.4^{g}	-15.2^{e}	-16.7^{f}
LSD value at 5%		0.011			1.44	

Treatments comprising sole groundnut was omitted

Cropping system C_2-Groudnut + Castor; C_3-Groundut + Blackgram; C_4-Grondnut + Sesame; C_5-Groundnut + Pearl millet; Irrigation Scheduling I_1- IW/CPE 0.50; I_2- IW/CPE 0.75; I_3- IW/CPE 1.0

Table 6: Effect of intercropping system and irrigation scheduling on the cost of cultivation of groundnut intercropping system (Mean data of 2017 and 2018)

Treatment	Total cost[1] ($ ha^{-1})			Gross benefit ($ ha^{-1})			Net income ($ ha^{-1})			Benefit: cost ratio		
	I_1	I_2	I_3	I_1	I_2	I_3	I_1	I_2	I_3	I_1	I_2	I_3
C_1	627.40	635.60	655.90	1449.20	1771.20	1668.80	821.80	1135.60	1012.80	2.31	2.79	2.55
C_2	608.00	616.10	636.50	1231.20	1562.00	1477.40	623.20	945.80	840.80	2.03	2.53	2.32
C_3	609.40	617.60	637.90	1505.30	1856.20	1734.90	895.90	1238.60	1097.00	2.47	3.00	2.72
C_4	597.10	605.30	625.60	1282.10	1611.40	1505.60	684.90	1006.10	880.00	2.15	2.67	2.41
C_5	595.90	604.10	624.40	1152.90	1499.00	1391.00	556.90	894.90	766.60	1.94	2.49	2.23

Cropping system C_1-Sole groundnut; C_2-Groudnut + Castor; C_3-Groundut + Blackgram; C_4-Grondnut + Sesame; C_5-Groundnut + Pearl millet; Irrigation Scheduling I_1- IW/CPE 0.50; I_2- IW/CPE 0.75; I_3- IW/CPE 1.0

land equivalent ratio (LER) of more than 1 indicating precedence over sole crop of groundnut under all irrigation regimes (Table 5). Groundnut + sesame at IW/CPE 0.75 resulted positive in comparison to intercropping with castor and pearl millet. It could be analyzed that each intercrop under the system should achieve groundnut yield of at least 14.3% under 6:1 ratio and 20% under 4:1 ratio of groundnut sole crop to remain an advantageous intercropping system. Groundnut + pearl millet at IW/CPE 0.50 noticed least values of LER indicating a less suitable intercropping system.

Relative Production Efficiency

Relative production efficiency could be simple way of determining the percent increase of productivity under intercropping system to that of sole crop of groundnut. Pooled data of groundnut + blackgram yielded significant ranging from 3.81% to 4.74% over other intercropping system (Table 5). Groundnut + pearl millet under various irrigation regimes recorded the minimum relative production efficiency (-20.4 to -15.2%). Similarly, irrigation scheduling IW/CPE 0.50 was identified less productive irrespective of intercropping system and was followed by IW/CPE 1.0. Groundnut intercropped with sesame also resulted less beneficial under all irrigation regimes but was found better over pearl millet and castor.

Economic Analysis

The economic analysis showed that the gross return under groundnut intercropping system ranged from 1152.90 to 1856.20 $ ha^{-1} (Table 4). Among different intercropping systems, highest gross benefit of 1856.20 $ ha^{-1} was noted for groundnut + blackgram followed by sole groundnut (1771.20 $ ha^{-1}) at irrigation regime of IW/CPE 0.75. While the highest total cost 655.90 $ ha^{-1} was noted in sole groundnut followed by groundnut + blackgram (637.90 $ ha^{-1}) 1.0. The increase under IW/CPE 1.0 was a result of frequent irrigation costs making it expensive which also decreased yields. Benefit:cost ratio (BCR) of the interaction ranged from 1.94 to 3.00 revealing lowest for groundnut +

pearl millet at IW/CPE 0.50 (1.94) while, highest was noted in groundnut + blackgram at IW/CPE 0.75 (3.00) indicating a promising cropping system.

Discussion

The performance of crops in an intercropping system depends on the mutual benefiting nature along with optimal irrigations favoring better output from the system. The higher growth performance of groundnut + blackgram combination may have been due to the higher thermal accumulation as a result of lesser shading effect from intercrop blackgram realizing higher yields. Similarly, Prasad *et al.* (2007) and Dapaah *et al.* (2014) also found better performance of groundnut due to increased photosynthetic efficiency as a result of lesser light interception. Climatological based irrigation scheduling of IW/CPE 0.75 attained higher growth parameters over the other irrigation scheduling as the optimum quantity of water supplied at appropriate interval might have resulted in better root growth without compensating the shoot growth of the crop. While, studies indicate that optimum irrigation frequency supplied to the crop could have retained adequate soil moisture content throughout the growth period of the crop which in turn facilitated better and proper utilization of nutrients thereby increasing yields (Behera *et al.*, 2015; Lokhande *et al.*, 2018).

Reduced WUE was observed in groundnut + pearl millet and groundnut + castor intercropping system as higher consumptive use of water was utilized by these systems along with lower equivalent yields together diminished the WUE (Arunkumar *et al.*, 2017). Irrigation scheduling based on IW/CPE 1.0 attained lower WUE on comparison to the other scheduling can be substantiated with the findings of Sounda *et al.* (2006) stated the frequent irrigations may have filled the root zone of the groundnut crop with water up to field capacity very frequently leading to increased evapotranspiration.

Relative crowding coefficient determined the competition effect of the system indicating groundnut grown in mixed population with blackgram has produced more yield than expected in pure stand. Likewise, aggressivity estimated the interspecies competitiveness of intercrops over groundnut in the system. The yield advantage and competitiveness realised by these intercropping systems was due to spatial and temporal complementary between both the component crops and optimum quantity of irrigation which may have resulted in effective utilization of nutrients from the soil (Singh and Ahlawat, 2011). Land equivalent ratio was used as a criterion to figure out the efficiency of intercropping system in using the resources from the environment as compared over the sole crop of groundnut. Relative production efficiency indicated the mutual benefiting nature of groundnut + blackgram combination along with optimal irrigations could have favoured better output from the system. Similar results could also be drawn from the findings of Kumar *et al.* (2010).

Light Interception recorded to assess the competition for solar radiation under intercropping situation. Light interception was significantly influenced by the growth of main crop as well the component crop as a resultant of the shade effect. Light interception was found to be inversely proportional to the growth and yield of the groundnut crop. The higher light interception and reduced LAI of groundnut crop under intercropping systems might have adversely affected the yields of the crop. Moreover, the effect of shading at flowering to pegging and pod filling stages were very sensitive and might have reflected negatively impacted on the growth and performance of the groundnut crop causing yield reductions (Awal *et al.*, 2006; Sandana *et al.*, 2012). While, Hang *et al.* (1984) and Rao and Mittra (1994) stated that excess light available to the crop after the harvest of intercrops had no significant effect on the performance of groundnut as it had already reached the maturity stage which could be the cause for lower yields of groundnut while intercropping with pearl millet than castor. Irrigation scheduling also significantly affected the light interception. Optimum water application resulted in better crop growth with higher growth rate of component crop influencing the light interception (Mathews *et al.*, 1991; Collino *et al.*, 2001).

Conclusion

Groundnut + blackgram intercropping system is best suited in the North-East state of Tamil Nadu along with application of irrigation at IW/CPE 0.75 together can produce higher groundnut pod yield and equivalent yield along with increased water use efficiency eventually increasing the monetary returns from the system.

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