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Influence of Irrigation Regimes on the Performance of Groundnut (*Arachis hypogaea*) under Intercropping Situation

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ABSTRACT

Background: The system output of groundnut based intercropping system depends on the selected companion crop as well as the frequency with which irrigation is supplied. This initiates a requisite to evaluate the performance of present traditional intercropping systems and thereby optimize the level of irrigation for both the crops under the system.

Methods: A two-year field experiment was conducted during the *rabi* season 2017-2019 at Oilseeds Research Station, Tamil Nadu Agricultural University, Tindivanam, Tamil Nadu, India The experiment was laid out in split plot design with three replications. Main plot comprised of five treatments with four intercrops *viz*., castor (TMV 5), blackgram (VBN 8), sesame (TMV 7), pearl millet (CO 10) and sole groundnut (TMV 13). The sub plot was assigned with three irrigation regimes based on IW/CPE ratio of 0.50, 0.75 and 1.0.

Result: Groundnut + blackgram combination recorded higher pod yield (6.31 g plant^{-1}), equivalent pod yield (1986 kg ha^{-1}) with increased water use efficiency (5.49 kg ha^{-1} mm^{-1}) and economic water productivity (` 309 ha^{-1} mm^{-1}) over sole groundnut while other intercropping combinations failed to express. Soil moisture extraction pattern was higher at top layers and decreased with soil depth. More frequent irrigations (IW/CPE 1.0) mismatched with the crop water requirement and resulted in higher consumptive water use (500.8 mm) with moisture extraction pattern from initial layers favouring evaporation losses. At peak growth stage (60 days after sowing) higher light interception was observed in groundnut + pearl millet (41.4%) followed by castor (38.2%) combinations which was the prime reason for decreased yields as groundnut is susceptible to shading. Therefore, groundnut + blackgram combination under *rabi* season when supplied with six irrigations at twenty days interval (based on IW/CPE 0.50) could significantly increase the productivity and monetary returns from the system.

Key words: Consumptive water use, Groundnut, Irrigation scheduling, Intercropping, Moisture extraction pattern, Per cent light interception.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.), an annual legume, originated from South America belonging to the family Fabaceae contains 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). Nearly 75% of groundnut cultivation is under rainfed farming with possibilities of erratic rainfall mostly under tropical and sub-tropical conditions make cultivation risky (Murungweni *et al.,* 2016). Adequate availability of water during flowering, gynophore formation and initial pod development stages largely determine its productivity (Parmar *et al.,* 2007).

Under such resource constraint situation with partial or total crop failure, adversely affect the future productivity as farmers tend to cultivate other cash crops like maize (*Zea mays*), cotton (*Gossypium hirsutum*) and soybean (*Glycine max*). This shortage of oilseeds along with pulses has also aggravated malnutrition in India. To compensate the lower productivity India imports 75% of vegetable oil making it the world's largest importer (15% of total worldwide imports).

On the other hand, rapid industrialization and urbanisation 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; Gunri *et al*., 2015).

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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 minimised (Natarajan and Willey, 1986).

Groundnut can be intercropped with sesame (*Sesamum indicum*), blackgram (*Vigna mungo*), pigeon pea (*Cajanus cajan*), pearl millet (*Pennisetum glaucum*), castor

(*Ricinus communis*), greengram (*Vigna radiata*), mothbean (*Vigna aconitifolia*) (Chandrika *et al.,* 2001; Honnali and Chittapur, 2014 and Bhuva *et al.,* 2017), but, selection of companion crop should not only be based on compatibility but also the present market price in order to increase the system productivity (Chaudhari *et al.,* 2017).

Nearly 60% of cultivation in India is rainfed farming and therefore water plays a crucial role where just 2 or 3 supplemental irrigations can perform wonders. But, due to a shift in trend towards industrialisation, intensive agriculture and so caused climate change has led water availability to become increasingly scarce and costlier (Hussain *et al*., 2018). Out of all the fresh water available nearly 80% is utilized for agriculture in India. Increased water use efficiency (WUE) can be attained through optimum application of irrigation by providing the water that match the crop evapotranspiration and at critical growth stages (Ibrahim *et al.,* 2002). 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).

The problem under irrigation scheduling for intercropping situation arises as different crops need different amount of water and optimization of irrigation for all cropping systems is needed. This needs to be ruled out by identifying the combination producing higher output in the same while having higher WUE. Therefore, this two-year field study was designed to explore the production potential of cropping system and evaluate its performance under different irrigation regimes and thereby quantify the water use efficiency.

MATERIALS AND METHODS

A field experiment was conducted at Oilseeds Research Station (12° 21′ N, 79° 66′ E and 45.6 m above mean sea level), Tindivanam, Tamil Nadu, India during *rabi* season (November-March) of 2017-18 and 2018-19. The soil at experimental site was sandy loam (20.4% coarse sand; 30.6% fine sand; 26.2% silt; 22.6% clay) medium in organic carbon (0.56%), low in available nitrogen (246 kg ha^{-1}), medium in phosphorus (24.1 kg ha^{-1}) and potassium (204 kg ha^{-1}). The weather parameters recorded during the trial is given in Table 1.

The experiment was laid out in split plot design with 5 intercropping treatments in the main plot *viz.,* sole groundnut, groundnut + castor (6:1), groundnut + blackgram (6:1), groundnut + sesame (4:1) and groundnut + pearl millet (4:1) and 3 treatments in the sub plot based on climatological irrigation scheduling using IW/CPE ratio of 0.50, 0.75 and 1.0. The crops were sown under replacement series on 12th of December, 2017 and 13th of December 2018, with groundnut (var. TMV 13) spacing of 30 × 10 cm (plant population: 333,333 ha^{-1}). Groundnut when intercropped with row ratio of 6:1 with castor (var. TMV 5: spacing 60 × 30 cm; plant population: 7,936 plants ha^{-1}) and blackgram (var. VBN 8: spacing 30 × 10 cm; plant population: 47,619 plants ha^{-1}) retained a plant population of 285,714 plants ha^{-1} and when intercropped with row ratio of 4:1 sesame (var. TMV 7: spacing 30 × 30 cm; plant population: 22,222 plants ha^{-1}) and pearl millet (var. CO 10: spacing 45 × 15 cm; plant population: 29,630 plants ha^{-1}) retained 266,666 plants ha^{-1} under replacement series. Recommended dose of fertilizer (25:50:75 NPK kg ha^{-1}) was applied as 50% nitrogen and potassium with 100% phosphorus as basal and the remaining 50% of nitrogen and potassium along with gypsum (400 kg ha^{-1}) at 45 days after sowing.

Initially one irrigation was provided on the day of sowing (DAS) followed by another at 5 DAS. The remaining irrigations were applied as per treatment based on daily pan evaporation data. Irrigation supplied to the crop was measured with an 18-inch cutthroat flume. 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 to calculate the volume of water supplied to the plot. Buffer channels were provided around each experimental plot to prevent irrigation water from entering the adjacent 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 (mm) and soil moisture extraction pattern of the crop.

Table 1: Monthly meteorological data of the experimental site.

Year and Month		Temperature (°C)			RH	Rainfall	PE	Wind speed	Solar radiation
		Max	Min	Mean	(%)	(mm)	(mm day^{-1})	(km hr^{-1})	(cal. cm^{-2})
2017	December	28.2	22.7	25.4	79.1	486.6	4.28	1.50	432.0
	January	29.7	20.2	25.0	70.9	0.2	4.29	1.47	490.3
	February	32.6	20.5	26.6	65.4	51.2	4.88	1.65	570.9
	March	36.2	22.5	29.4	62.3	115.0	5.20	3.18	550.2
2018	December	30.0	22.7	26.4	72.2	38.6	4.03	1.35	406.3
	January	29.2	20.0	24.6	81.1	0.5	4.19	3.14	490.1
	February	31.2	22.3	26.8	82.0	1.0	5.24	3.48	548.9
	March	32.9	23.4	28.2	78.4	0.0	5.85	4.21	605.6

Max= Maximum, Min= Minimum, RH= Relative humidity, PE= Pan evaporation per day.

Total consumptive use =

$$\sum_{i=1}^{n} \text{moisture depletion} + \text{soil moisture contribution} + \text{ER}$$

Where, soil moisture depletion was calculated using Dastane (1972) formula:

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

Where,
d = Moisture deficit in the root zone.
M_1^i = Soil moisture in the i^{th} layer of profile 24 hours after irrigation.
M_2^i = Soil moisture in the i^{th} layer of profile 24 hours before the next irrigation.
ASi = Bulk density of the i^{th} layer (g/cc).
Di = Depth of the i^{th} layer (cm).
ER = Effective rainfall.

Both the sole and intercrops were harvested manually, sundried and threshed manually. Groundnut was harvested on 26th of March during both the consecutive years. Observations of relevant parameters of all the crops were recorded as per standard procedure. The yields of different intercrops were converted into groundnut equivalent yield based on price of the produce and expressed as kg ha^{-1}. Water use efficiency (WUE) was calculated from the amount of yield that was produced from the unit consumptive use of water (kg ha^{-1} mm^{-1}).

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

Similarly, economic water productivity (EWP) was calculated as a function of gross income to the total water used by the crop throughout its growth and expressed in ` ha^{-1} mm^{-1}.

$$EWP = \frac{\text{Gross income (` ha}^{-1})}{\text{Total consumptive use (mm)}}$$

The economic analysis was formulated as per the standard procedure of CIMMYT (1988). For each system, partial budgeting was calculated to determine the expenses incurred and net returns using the market price during the experiment.

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 AM, 12:00 PM and 2:00 PM. 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 was done by Rosenthal and Gerik (1991), Chelliah (1996) and Kiniry *et al*. (2005) 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.

Statistical Analysis of variance (ANOVA) was performed with the SAS software (SAS 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 AND DISCUSSION

Yield and equivalent yield

Groundnut pod yield was significantly affected by intercropping and ranged from 4.72 g $plant^{-1}$ to 6.31 g $plant^{-1}$. Groundnut when intercropped with blackgram recorded higher pod yield of 6.31 g $plant^{-1}$ and similarly the equivalent yield was (1986 kg ha^{-1}) 4.4 per cent over the sole crop (1902 kg ha^{-1}). While intercropping with pearl millet, the performance of groundnut reduced by 17.3 per cent (4.72 g $plant^{-1}$), which eventually decreased the equivalent yield by 17.2 per cent over sole groundnut (Table 2).

This was probably due to the fact that sole groundnut and groundnut + blackgram received much higher solar radiation in comparison to association with other intercrops, exerted higher stress thereby producing lesser number of leaves and reduced yields (Stirling *et al*., 1990). The horizontal spreading nature of pearl millet roots left lesser space for groundnut pods to develop which simultaneously noted increased competition for natural resources significantly decreased the yield of main crop (groundnut).

Irrigation scheduled at IW/CPE 0.50 (6.06 g $plant^{-1}$; equivalent yield of 1946 kg ha^{-1}) outperformed over IW/CPE 0.75 (5.66 g $plant^{-1}$; equivalent yield of 1817 kg ha^{-1}) and IW/CPE 1.0 (4.79 g $plant^{-1}$; equivalent yield of 1549 kg ha^{-1}) with lesser yield when subjected to more frequent irrigation (Table 2).

The adequate application of irrigation led to optimum maintenance of soil moisture content within the soil system resulted higher water uptake under field capacity which frequent irrigations failed to supply. The increased water uptake facilitated better nutrient uptake from the system via mass flow. Moreover, frequent irrigations led to increased leaching effect reducing the fertilizer use efficiency. Therefore, judicious application of irrigation promoted more yield attributes significantly increasing the yield. The results are in similarity to the findings of Raskar and Bhoi (2003) and Bandyopadhyay *et al.* (2005).

Irrigation efficiency

Groundnut as such utilized 390.3 mm with water use efficiency of 5.11 kg ha^{-1} mm^{-1} and economic water productivity of ` 292 $ha^{-1}$ $mm^{-1}$ while under blackgram combination it reduced to 381.0 mm thereby increasing the WUE (5.49 kg $ha^{-1}$ $mm^{-1}$) and EWP (` 309 ha^{-1} mm^{-1}) (Table 2). Intercrop producing more biomass per unit area (pearl millet > castor > sesame) utilized more water from soil. Less frequent irrigation (IW/CPE 0.50) for groundnut produced more output along with reduced water application (323 mm) and thereby significantly increased the WUE (6.04 kg ha^{-1} mm^{-1}) and EWP (` 340 ha^{-1} mm^{-1}).

Frequent irrigations could have filled the root zone of the crops with water up to field capacity very frequently leading to increased evapo-transpiration losses (Sounda *et al.*, 2006). Moreover, the conductive effect of wet rhizosphere for longer period of time created a higher vapour pressure gradient between canopy air and atmospheric air which might have been responsible for increased evaporation consequential of higher consumptive water use of groundnut (Patel *et al.,* 2008).

Soil moisture extraction

Soil moisture extraction by the crops decreased with increase in depth up to 75 cm indicating higher extraction at initial layers and might have also been influenced by evaporation losses (Table 3). The mean data of *rabi*, 2017-18 and 2018-19 observed higher soil moisture uptake in sole groundnut (25.16%) followed by groundnut + blackgram (25.06%) at initial 15cm and thereafter the trend reversed with the later extracting lesser soil moisture at lower depths. Among the other intercrops, castor noted lesser extraction of soil moisture at initial 15 cm (24.51%) but as the depth increased noted increased extraction with highest percentage at the depth of 60-75 cm (14.08%). Irrigation scheduling at IW/CPE 1.0 recorded increased soil moisture uptake at initial 0-15 cm (25.17%) while it reduced at deeper layers (60-75 cm: 13.63%). Soil moisture extraction pattern predominantly depended on the length of intermittent duration of water applied to the crop. Frequent the irrigation more was the moisture availability in the surface layer where the crop utilized with lesser root penetration. Hence, Irrigation scheduling with IW/CPE 1.0 made available for crop to extract more moisture from the initial 0-30cm depth, while IW/CPE 0.50 resulted in extraction from 30-75cm depth of the soil. Similar findings were reported by Gulati *et al.* (2001).

Table 2: Effect of Intercropping and Irrigation scheduling on the yield, equivalent yield, consumptive water use, water use efficiency and water productivity of groundnut (Pooled data of 2 years).

Treatments	Groundnut yield (g $plant^{-1}$)	Equivalent pod yield (kg ha^{-1})	Consumptive water use (mm)	Water use efficiency (kg ha^{-1} mm^{-1})	Economic water productivity (` ha^{-1} mm^{-1})
Intercropping					
C_1: Sole Groundnut	5.71^{b}(1902)	1902^{a}	390.3^{b}	5.11^{a}	292^{a}
C_2: Groundnut + Castor	5.28^{bc}(1509)	1669^{bc}	411.8^{a}	4.26^{b}	243^{b}
C_3: Groundnut + Blackgram	6.31^{a}(1803)	1986^{a}	381.0^{bc}	5.49^{a}	309^{a}
C_4: Groundnut + Sesame	5.50^{b}(1468)	1723^{b}	400.8^{ab}	4.53^{b}	254^{b}
C_5: Groundnut + Pearl millet	4.72^{c}(1259)	1573^{c}	420.8^{a}	3.94^{bc}	224^{bc}
LSD @ 5%	0.40	140	14.2	0.55	30.4
Irrigation scheduling					
I_1: IW/CPE 0.50	6.06^{a}(1748)	1946^{a}	323.2^{b}	6.04^{a}	340^{a}
I_2: IW/CPE 0.75	5.66^{a}(1632)	1817^{a}	378.9^{b}	4.84^{b}	275^{b}
I_3: IW/CPE 1.00	4.79^{b}(1383)	1549^{b}	500.8^{a}	3.12^{c}	178^{c}
LSD @ 5%	0.60	178	63.2	1.09	60.8

Table 3: Effect of Intercropping and Irrigation scheduling on the moisture extraction pattern (Pooled data of 2 years).

Treatments	Soil Moisture Extraction Pattern (%)				
	0-15 cm	15-30 cm	30-45 cm	45-60 cm	60-75 cm
Intercropping					
C_1: Sole Groundnut	25.16	23.34	20.49	17.25	13.76
C_2: Groundnut + Castor	24.51	22.73	20.91	17.78	14.08
C_3: Groundnut + Blackgram	25.06	23.40	20.51	17.25	13.77
C_4: Groundnut + Sesame	24.78	23.00	20.73	17.60	13.90
C_5: Groundnut + Pearl millet	24.53	22.94	20.88	17.68	13.97
Irrigation scheduling					
I_1: IW/CPE 0.50	24.49	22.81	20.87	17.73	14.10
I_2: IW/CPE 0.75	24.76	23.02	20.74	17.53	13.96
I_3: IW/CPE 1.00	25.17	23.42	20.50	17.28	13.63

Table 4: Effect of Intercropping and Irrigation scheduling on the Light Interception on groundnut (Pooled data of 2 years).

Treatments	30 DAS	60 DAS	90 DAS	Mean light interception
Intercropping				
C_1: Sole groundnut	16.8^c	26.1^b	27.1^b	23.4^b
C_2: Groundnut + Castor	32.3^a	38.2^a	40.5^a	37.0^a
C_3: Groundnut + Blackgram	17.0^c	26.2^b	25.0^b	22.8^b
C_4: Groundnut + Sesame	24.5^b	32.9^{ab}	24.2^b	27.3^b
C_5: Groundnut + Pearl millet	34.1^a	41.4^a	23.4^b	33.0^a
LSD @ 5%	7.26	6.00	4.36	5.56
Irrigation scheduling				
I_1: IW/CPE 0.50	25.9	33.8	29.0	29.6
I_2: IW/CPE 0.75	24.8	32.8	27.9	28.5
I_3: IW/CPE 1.00	24.2	32.3	27.3	28.0
LSD @ 5%	NS	NS	NS	NS

Light interception

Light interception recorded to assess the competition for solar radiation in intercropping situation was significantly influenced by the growth of main crop as well the component crop as a resultant of the shade effect (Table 4). At 30 DAS the pooled data of *rabi*, 2017-18 and 2018-19 noted higher LI in groundnut + pearl millet (34.1%) at par with groundnut + castor system (32.3%) while lesser LI was in sole groundnut system (16.8%) at par with groundnut + blackgram (17.0%). Light interception at 60 DAS also noted a similar trend as at 30 DAS where the interaction revealed higher light interception in groundnut + pearl millet system (41.4%).

Light interception was found to be inversely proportional to the growth and yield of the groundnut crop where higher light interception and lower leaf area index of groundnut crop in 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 higher light interception might have reflected a negative impact on the growth and performance of the groundnut crop causing further yield reductions (Awal *et al*., 2006; Sandaña *et al*., 2012). The effect of irrigation regimes was non-significant throughout the crop growth but slight deviations were noted in IW/CPE 0.50 might be probably due to increased crop growth.

At 90 DAS intercrops blackgram (65-70 days), sesame (82-84 days) and pearl millet (86-89 days) were harvested which influenced on the light interception on the main crop groundnut (105 days). It was observed that groundnut + pearl millet (23.4%) combination noted lesser light interception whereas the same system up to 60 DAS recorded the highest light interception (41.4%). Further, at 90 DAS the only standing intercrop castor (duration 105-120 days) induced LI of 40.5% followed by sole groundnut (27.1%) over other harvested intercrop combinations.

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 (Azam-Ali *et al*., 1990; Matthews *et al*., 1991; Collino *et al*., 2001).

CONCLUSION

Groundnut based intercropping system is highly potential over sole cropping system only under appropriate selection of companion crop. Hence, groundnut + blackgram intercropping system was best suited while, other intercrops like pearl millet, castor, sesame decreased the system productivity over sole cropping system. From the present study, groundnut + blackgram during the *rabi* reason (November to March) irrigated based on IW/CPE 0.50, scheduled at twenty days interval (total six irrigations - inclusive of one at sowing and another as life irrigation) was found sufficient to produce higher groundnut yield and equivalent yield with increased water use efficiency and water productivity for the North-East state of Tamil Nadu, India.

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