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Irrigation and nutrient management for yield augmentation of summer sesame (*Sesamum indicum* L.)

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ABSTRACT

A field experiment was conducted during summer seasons of 2010 and 2011 at Bhubaneswar in a sandy loam soil to study the response of sesame to irrigation and nutrient management practices. Four levels of irrigation viz., IW/CPE - 0.6, 0.8, 1.0 and 1.2 were allotted to the main plots and four fertility levels viz., 60 + 13.2 + 25kg N + P + K ha^{-1} (RDF), 30 + 6.6 + 12.5 Kg N + P + K ha^{-1} (50% RDF), 30 + 6.6 + 12.5 kg N + P + K ha^{-1} with 5t ha^{-1} FYM, and 5 t FYM ha^{-1} alone to the sub plots in a split plot design with three replications. Yield attributes were higher for IW/CPE of 1.0 resulting in higher seed (808 kg ha^{-1}) and oil (407 kg ha^{-1}) yields and net returns (Rs.4258 ha^{-1}) with consumptive use of 51.8 cm and water use efficiency of 15.7 kg/ha-cm. Integrated nutrition i.e. 50% RDF + 5 t FYM ha^{-1} expressed better growth and yield attributes with the highest seed (874 kg ha^{-1}) and oil (437 kg ha^{-1}) yields, net return (Rs.4659 ha^{-1}), consumptive use (53.6 cm) and water use efficiency (16.3 kg/ha-cm) and nutrient uptake (29.6kg N, 11.2 kg P and 29.9kg K ha^{-1}). The crop irrigated at IW/CPE of 1.0 and supplied with 50% RDF + 5 t FYM ha^{-1} produced maximum seed (916 kg ha^{-1} and oil (464 kg ha^{-1}) yields.

Key words**:** Irrigation, nutrient management, sesame, summer season

The Technology Mission on Oilseeds, launched in 1986, envisaged a production boost largely contributed by oilseeds like rapeseed and mustard, groundnut, soybean and sunflower. India became self-sufficient in edible oils by early 90's and thereafter, the gap between demand and production have widened radically. At present, India imports more than 40% of its annual edible oil need amounting to Rs.11,000 crores to the exchequer. Sesame (*Sesamum indicum* L.), the ancient oilseed crop of India having 50% oil, 25% protein and vitamins, minerals and antioxidants is grown in 1.74m ha area with productivity of 421 kg ha^{-1} (OAS, 2009). In eastern India, the crop is successfully grown, in all the seasons and more so in the summer season. But, its productivity is low because it is grown in marginal lands with least external nutrient supply and limited irrigations. However, Garai and Datta (2002) recorded positive response of sesame to application of irrigation in critical growth stages. Similarly, Subrahmaniyan *et al.* (2001) and Nagavani *et al.* (2001) reported that increasing NPK level up to 150% resulted in better yield attributes and yield. Application of 75 + 25.8 + 49.8 kg N + P + K ha^{-1} increased biometric parameters, yield attributes and yields of sesame in West Bengal (Sarkar and Pal, 2005). Sridevi *et al.* (2005) found that conjunctive use of inorganic fertilizers with organics influenced soil water content and increased seed yield of sesame. However, studies on response of the crop to irrigation regimes under different fertility levels in general and to INM practices in particular are scanty. Hence, this study was made to find out the optimum irrigation and nutrition to summer sesame.

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MATERIALS AND METHODS

The experiment was conducted at the Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar, situated at 20^{0}15' N, 85^{0}52' E and 25.9m above mean sea level during the summer seasons of 2010 and 2011. The soil of the experimental site was sandy loam in texture with pH 5.6, organic carbon 3.1 g kg^{-1} and available N, P and K, 170, 42 and 130 kg ha^{-1}, respectively. The bulk density of the soil was 1.64 Mg m^{-3}, field capacity 13.1%, permanent wilting point 4.7% w/w and available soil moisture 2.08 cm (0-30 cm soil depth). The total amounts of rainfall received during the cropping seasons were 85.4 and 11.7 mm, respectively. The mean maximum and minimum temperatures of both the seasons were within the optimal range of 35.5 to 36^{0}C and 22.5 to 23^{0}C, respectively. The experiment was laid out in a split-plot design with three replications. Four levels of irrigation *viz*., IW/CPE (irrigation water/cumulative pan evaporation) ratio of 0.6 0.8, 1.0 and 1.2 were assigned to the main plots (60m^2 each) and four fertility levels viz., 60 + 13.2 + 25 kg N + P + K ha^{-1} (RDF), 30 + 6.6 + 12.5 kg N + P + K ha^{-1} (50% RDF), 50% RDF + 5t FYM ha^{-1}and 5t FYM ha^{-1} (0.52 % N) alone to the sub plots (11.25 m^2 each). A fixed quantity of 60 mm of water measured through a 7.5 cm Parshall flume was applied at each irrigation. In 2010 and 2011, a total of 3 and 4 , 4 and 6, 5 and 7, and 6 and 8 irrigations were applied at IW/CPE ratio of 0.6, 0.8 1.0 and 1.2, respectively. As regards to fertilizers, N was applied in two splits i.e., 50% as basal and 50% at 21 DAS (days after sowing) and P and K were applied as basal according to the treatments. Sesame (cv Uma) @ 5 kg seed ha^{-1} was sown at 30 x 10 cm spacing in the second week of February and harvested in second week of May in both the years. Observations on crop growth, yield attributes and yield were recorded. Growth analysis parameters were calculated using standard formulae.

Nutrients and oil content were estimated following prescribed procedures (Jackson, 1967). Consumptive use and water use efficiency were calculated based on the periodic observations on soil moisture. The economics was calculated as per the official price for different commodities.

RESULTS AND DISCUSSION

Growth

Data on growth of plants due to irrigation and fertility levels (Table 1) revealed that irrigating the sesame crop at IW/CPE ratio of 1.2 produced significantly the tallest plants, maximum number of branches plant^{-1}, leaf area index (LAI) at 65 DAS and dry matter production at harvest. The growth parameters showed a decreasing trend with decreasing IW/CPE ratio up to 0.6. Water is essential to build up tissues and carry out biochemical and physiological activities within the plant body to express itself fully. Hence, maintaining optimum soil water regime in all the physiological stages might be the reason for manifestation of higher growth and dry matter production. The crop growth rate (CGR) and net assimilation rate (NAR) at 35-50 days were higher for IW/CPE ratio of 1.0 and relative growth rate (RGR) at 35-50 days for the ratio of 1.2. However, the above three parameters were at par for both the ratios. This might be due to the reason that beyond a certain limit, irrigation water may not have any significance for plant activity.

Application of 50% NPK + 5 t FYM ha^{-1} registered the tallest plants and maximum number of branches plant^{-1}, LAI and dry matter production. This might be due to the beneficial effect of combined use of fertilizers and FYM during summer season where, FYM improved the physico-chemical and biological properties of soil such as water holding capacity, availability of macro and micronutrients and better microbial activity in the root zone of plant to support vegetative growth. While, Sarkar and Pal (2005) reported positive response of sesame to NPK application, Jain *et al.* (2000) reported improved vegetative growth due to combined application of FYM with fertilizers. The interaction effect of irrigation and fertilizer was significant for all growth parameters.

Table 1: Effect of irrigation and fertility levels on biometric observation of summer sesame (pooled)

Treatment	**Plant height (cm)**	**Branches plant^{-1}**	**LAI (65 DAS)**	**Dry matter production at harvest (g plant^{-1})**	**CGR (g m^{-2}day^{-1}) (35-50 days)**	**RGR (g g^{-1}day^{-1}) at 35-50 days**	**NAR (g m^{-2} leaf area day^{-1}) at 35-50 days**
Irrigation (IW/CPE)							
I_1=0.6	81.0	5.6	2.15	7.30	7.36	0.058	6.845
I_2=0.8	82.0	6.0	2.19	7.89	8.41	0.061	7.006
I_3=1.0	85.3	6.4	2.26	8.89	9.37	0.064	7.568
I_4=1.2	89.4	6.8	2.36	8.58	9.34	0.065	7.256
SEm(±)	1.01	0.06	0.02	0.05	0.17	0.001	0.142
LSD (0.05)	3.10	0.17	0.05	0.14	0.51	0.003	0.438
Fertilizers kg ha^{-1}(N:P:K)							
60+13.2+25	85.6	6.5	2.32	8.23	8.93	0.061	1.176
30+6.6+12.5	84.1	6.1	2.19	7.85	8.37	0.063	7.168
30+6.6+12.+ FYM 5t ha^{-1}	86.5	6.7	2.39	8.52	9.44	0.063	7.170
FYM 5t ha^{-1}	81.2	5.5	2.06	7.56	7.89	0.062	7.356
SEm(±)	**0.657**	**0.06**	**0.02**	**0.05**	**0.13**	**0.001**	**0.137**
LSD (0.05)	**1.63**	**0.17**	**0.06**	**0.13**	**0.38**	**0.002**	**NS**
I x F							
SEm(±)	**1.06**	**0.14**	**0.03**	**0.10**	**0.29**	**0.002**	**0.410**
LSD (0.05)	**NS**	**0.41**	**0.09**	**0.29**	**0.88**	**0.006**	**1.222**

Table 2: Effect of irrigation and fertility levels on yield attributes, seed and oil yield and economics of summer sesame cultivation (Pooled)

Treatment	Capsules plant^{-1}	Seeds capsule^{-1}	Test weight(g)	Seed yield (kg ha^{-1})			Biological yield (t ha^{-1})	Harvest index (%)	Oil yield (kg ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
				2010	2011	Pooled					
Irrigation (IW/CPE)											
I_1=0.6	43.3	62	2.99	661	722	692	2.52	27.36	329	3286	0.47
I_2=0.8	48.7	63	3.17	742	748	745	2.68	27.77	361	3688	0.50
I_3=1.0	61.3	68	3.42	807	811	808	2.79	28.93	407	4258	0.55
I_4=1.2	57.9	66	3.41	805	790	799	2.79	28.68	392	3738	0.46
SEm(±)	**0.66**	**0.84**	**0.11**	**7.6**	**7.0**	**5.1**	**--**	**0.16**	**3.8**	**--**	**--**
LSD (0.05)	**2.28**	**2.91**	**0.37**	**26.2**	**24.1**	**15.3**	**--**	**NS**	**11.4**	**--**	**--**
Fertilizers kg ha^{-1}(N:P:K)											
60+13.2+25	57.2	66	3.37	806	829	818	2.79	29.85	393	4555	0.60
30+6.6+12.5	50.0	63	3.16	705	706	706	2.57	27.90	347	3676	0.54
30+6.6+12+ FYM 5t ha^{-1}	59.0	67	3.41	850	898	874	2.96	29.51	437	4659	0.56
FYM 5t ha^{-1}	45.2	63	3.06	654	639	647	2.47	26.14	313	2043	0.27
SEm(±)	**0.96**	**0.77**	**0.12**	**8.8**	**5.7**	**5.1**	**--**	**0.17**	**3.4**	**--**	**--**
LSD (0.05)	**2.81**	**2.24**	**0.35**	**25.6**	**16.6**	**14.4**	**--**	**0.49**	**8.7**	**--**	**--**
I x F											
SEm(±)	**1.80**	**1.55**	**0.25**	**16.99**	**12.08**	**10.28**	**--**	**0.35**	**6.89**	**--**	**--**
LSD (0.05)	**5.38**	**4.77**	**0.77**	**51.43**	**37.42**	**28.98**	**--**	**1.00**	**NS**	**--**	**--**

Yield attributes

Data on yield attributes in Table 2 revealed that IW/CPE ratio of 1.0 recorded significantly the maximum number of capsules/plant. Seeds/ capsule and test weight were also the highest for the same treatment but were at par with those of 1.2 IW/CPE ratio. The lowest values of the yield attributes were observed in case of IW/CPE of 0.6 ratio. Favourable plant water balance maintained through irrigation might have resulted in better translocation of photosynthates and maintenance of cell turgidity, consequently leading to higher yield traits. Similar finding was also reported by Saren *et al.* (2005). Integrated application of 50% NPK + 5 t FYM ha^{-1} registered maximum capsules/ plant and seeds/ capsule, but was at par with those of RDF. Jain *et al.* (2000) also recorded similar observations.

Seed and oil yield

Maximum seed, oil and biological yield was recorded for IW/CPE ratio of 1.0. Further increase in IW/CPE ratio resulted in slight decline in seed yield and significant decrease in oil yield whereas, the biological yield remained the same. Application of 50% NPK + 5 t FYM ha^{-1} registered significantly higher seed and oil yields. The minimum yields were recorded due to application of 5 t FYM ha^{-1} alone. This might be due to better manifestation of the yield traits under integrated nutrient management practice. Application of only organic nutrient produced significantly the minimum yield (647 kg ha^{-1}). Gopinath *et al*. (2011) also suggested that only organic nutrients do not increase the yield of sesame. Accumulation of dry matter in plants is important in producing a plant capable of high grain yield. Similar findings were also observed by De *et al.* (2002) for irrigation and Imayavaramban *et al*. (2002) for integrated nutrient management. The interaction effects of irrigation and fertility levels were significant for seed and oil yields. Sesame crop under integrated supply of plant nutrients (50% RDF + 5 t FYM ha^{-1}) produced the highest seed and oil yields whereas the parameters were at par for IW/CPE ratios of 1.0 and 1.2 (Table 3). Increase in seed yield due to optimal irrigation at IW/CPE ratio of 1.0 over sub-optimal irrigation at the ratio of 0.6 was observed for all the nutrient management treatments. In the above case, yield increased by 25% for sole application of 5 t FYM ha^{-1} followed by 100% RDF (18%) and 50% RDF + 5 t FYM ha^{-1} (16.7%), the lowest being at sub-optimal supply of plant nutrient i.e. 50% RDF (8.9%). This suggests that adequate nutrient and irrigation supply is required to realize higher productivity of summer sesame in sandy loam soil with low fertility status and soil organic carbon content.

Water use

The consumptive use of water at IW/CPE ratio of 1.2 was the maximum (53.6 cm) and was 11.2, 25.2 and 54.8% higher than that of 1.0, 0.8 and 0.6 ratio, respectively (Table 4). This might be due to the fact that frequent irrigation increased the evaporation loss at a greater rate from the wet surface layer for most of the times and the plants with adequate vegetative growth transpired luxuriously. As regards water use efficiency, the trend was reverse because of higher yield in the numerator and still higher consumptive use in the denominator.

The crop supplied with 50% RDF + 5 t FYM ha^{-1} consumptively used maximum water (53.6cm) which was 4.1, 19.6 and 25.5% higher than 100% RDF, 50% RDF and FYM alone, respectively. Under integrated nutrient supply system (50% NPK + 5 t FYM ha^{-1}), the available water in soil was more and the biological yield was also the highest. When FYM was applied alone, even though water was available, plants might not have used it because of less vigour, resulting in the lowest consumptive water use by the crop. The increase or decrease in seed yield due to different nutrient management practices in summer sesame commensurate with the corresponding water use by the crop resulting in similar trend in water use efficiency of the crop to its consumptive use of water. The results are in conformity with the findings of Dutta *et al.* (2000).

Nutrient uptake

Uptake of N, P and K was the highest when the crop was irrigated at IW/CPE ratio of 1.0. This might be due to optimal air and water balance in the soil, which consequently increased the mobilization of the nutrients along with the absorbed water through well developed root system. Under higher level of irrigation, air-water imbalance and leaching loss of some nutrients like nitrogen might not have made it available to plants. At lower irrigation frequency insufficient soil water might not have facilitated mass flow, root interception and diffusion processes to mobilize the nutrients for uptake. The uptake pattern mostly followed the biomass yield trend due to different irrigation regimes, which was in conformity with Dutta *et al.* (2000).

Integrated use of 50% RDF + 5 t FYM ha^{-1} resulted in higher total N, P and K uptake, mostly because of the established beneficial effect of FYM in improving the physico-chemical and microbial properties of soil enhancing availability of nutrients. However, in most of the cases uptake due to integrated use of nutrients was on a par with that of 100% RDF.

Economics

Application of irrigations at IW/CPE ratio of 1.0 registered the highest net returns and benefit: cost ratio and those were minimum with 0.6 ratio. Integrated use of 50% RDF + 5 t FYM ha^{-1} resulted in the highest net returns followed by RDF alone. However, benefit: cost ratio was the maximum for the latter because of relatively lower cost of inorganic fertilizers than the organic source i.e., FYM, per unit quantity of plant nutrients. Sole application of 5 t FYM ha^{-1} registered the minimum net return and benefit: cost ratio because of lower seed yield and relatively higher cost of FYM.

The present study revealed that application of 5 to 7 irrigations at IW/CPE of 1.0 and integrated use of 50% RDF (30+6.6+12.5 kg N+ P + K ha^{-1}) along with 5 t FYM ha^{-1} to sesame crop grown in sandy loam soil during summer season can be recommended for higher productivity and profitability. Nutrient dynamics and soil extraction pattern in the effective root zone depth needs to be studied under different irrigation and nutrient management practices.

Table 3: Interaction effect of irrigation and fertility levels on seed and oil yield of summer sesame (pooled)

Irrigation/ fertility level	Seed yield (kg ha^{-1})					Oil yield (kg ha^{-1})				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
I_1=0.6	752	671	785	559	691.8	332	321	338	264	313.8
I_2=0.8	790	683	884	625	745.5	369	328	421	313	357.8
I_3=1.0	890	731	916	700	809.3	448	346	464	355	403.3
I_4=1.2	839	738	912	702	797.8	405	378	454	334	392.8
Mean	817.8	705.8	874.3	646.5		388.5	343.3	419.3	316.5	
		I x F	**F x I**				**I x F**	**F x 2I**		
SEm(±)		**10.28**	**10.24**				**8.8**	**9.82**		
LSD(0.05)		**28.98**	**28.88**				**26.01**	**28.65**		

Table 4: Effect of irrigation and fertility levels on consumptive use and use efficiency of water (kg ha^{-1}-cm) and N, P and K uptake of summer sesame (mean)

Treatment	Consumptive use (cm)	Water use efficiency	Nutrient uptake (kg ha^{-1})			
			N	P	K	Total
Irrigation (IW/CPE)						
I_1=0.6	37.2	18.6	21.5	8.1	22.7	52.2
I_2=0.8	46.0	16.3	24.8	9.0	25.2	58.9
I_3=1.0	51.8	15.7	29.0	10.4	28.1	67.4
I_4=1.2	57.6	13.9	27.1	9.4	28.0	64.9
SEm(±)			0.35	0.14	0.48	0.45
LSD (0.05)			1.19	0.49	1.65	1.31
Fertilizers kg ha^{-1}(N:P:K)						
60+13.2+25	51.5	15.9	31.6	10.0	27.3	68.8
30+6.6+12.5	44.8	15.8	21.6	8.4	23.8	53.9
30+6.6+12. + FYM 5t ha^{-1}	53.6	16.3	29.6	11.2	29.9	70.6
FYM 5t ha^{-1}	42.7	15.2	19.6	7.7	22.9	50.2
SEm(±)			**0.28**	**0.25**	**0.54**	**0.70**
LSD (0.05)			**0.79**	**0.72**	**1.57**	**2.04**
I x F						
SEm(±)			**0.58**	**0.42**	**0.52**	**0.58**
LSD (0.05)			**1.75**	**NS**	**NS**	**NS**

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