Journal of Crop and Weed, 13(1): 01-06 (2017)

Improving growth and productivity of linseed (*Linum usitatissimum*) using mulches under different levels of irrigation

S. SARKAR AND A. SARKAR

Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, Pin- 741252

Received : 10-02-2017 ; Revised : 20-04-2017 ; Accepted : 24-04-2017

ABSTRACT

A field experiment was conducted at BCKV farm, West Bengal during rabi 2010-12 to evaluate the effect of irrigation and mulch on growth and productivity of linseed (Linum usitatissimum). Irrigation at IW/CPE of 0.6 showed 6.72 and 17.63% higher seed yield compared to IW/CPE of 0.4 and rainfed. Treatment receiving black polythene mulch registered about 4.33, 8.72 and 14.76% higher seed yield over straw @ 5 t ha^{-1}, water hyacinth @ 5t ha^{-1} and no mulch. Water use efficiency was highest with rainfed treatment receiving black polythene. Combining irrigation at IW/CPE of 0.6 and black polythene led to the maximization of net return and B:C ratio and proved as best.

***Keywords* :** Economics, irrigation, linseed, mulch, water use efficiency yield

Linseed (*Linum usitatissimum*) is an important oilseed crop in India, next to rapeseed-mustard with average productivity of 502 kg ha^{-1}, production of 1.486 lakh tones and grown in 2.963 lakh hectare area (CSAUAT, 2013-14). It is a great vegetarian source of the Omega 3 essential fatty acid, Alpha-Linolenic Acid (ALA), containing twice as much as fish oil. These essential fatty acids have anti-inflammatory properties, offering health benefits to a number of chronic diseases such as Heart disease, Diabetes and Arthritis. Though linseed can be grown for dual purpose- seed and fiber but in India it is mainly grown for seeds, for extracting oil. One of the major constraints affecting crop production is chronic water limitation (Amir and Sinclaire, 1996). Water is an indispensable, finite and scarce natural resource. With the decline of water table and shortage of available water, linseed is mainly grown as rainfed crop and is prone to water stress. Therefore, irrigation scheduling is the most prime factor which ensures timely and adequate amount of water to the crop in best possible way for optimizing agricultural production. At the same time, the need to meet increasing demand for food will require increased production per unit of water. Mulches can improve water productivity and yield through increase in water retention. Mulches enhance moisture availability period, reduce evaporation loss of water and maintain soil temperature. Organic mulches add organic matter to the soil after degradation and thus enhance nutrient status of soil. But organic mulches step behind the non degradable polythene mulch in respect of enhancement of crop water use efficiency and productivity. Most of the earlier studies have examined the significant influence of irrigation and mulch on growth and yield of crops (Digra *et al*., 2016; Kaur and Vashist, 2016). Therefore, the present study was undertaken in this background to assess the potential role of mulches (black polythene, straw and water hyacinth) in improving the performance of linseed in comparison with no mulch under various irrigation levels.

MATERIALS AND METHODS

A field experiment with linseed was conducted during the winter (*rabi*) season of 2010-12 at Research Farm, Bidhan Chandra Krishi Viswavidyalaya, Kalyani (at 22°58' N latitude and 88°3' E longitude with an altitude of 9.75 m above the mean sea level) in West Bengal. The soil of the experimental site was alluvial and sandy loam in texture with p^H 7.86, Organic carbon 0.61 %, available N 250.12 kg ha^{-1}, available P and K of 15.81 and 153.22 kg ha^{-1}, respectively The moisture content at field capacity was 21.2% and at permanent wilting point 9.5%. The experiment was laid out in Split plot design with 3 replications. Main plot treatments consisted of three levels of irrigation, viz. Rainfed (I_1), Irrigation at IW/CPE of 0.4 (I_2), Irrigation at IW/CPE of 0.6 (I_3) and sub-plots with four levels of mulch, viz. No mulch, Water hyacinth @ 5 t ha^{-1}, Straw mulch @ 5 t ha^{-1} and Black polythene with 25 micron thickness. Recommended doses of N, P_2O_5 and k_2O @ 60: 30: 30 kg ha^{-1} were applied through urea, single superphosphate and muriate of potash, respectively during both the years of experiment. Full dose of phosphorus, potassium and half amount of nitrogen were applied as basal and remaining half dose of nitrogen was applied 45 DAS. Linseed 'Neela (B-67)' was sown in rows, 30 cm apart using 20 kg seeds ha^{-1} in 2nd week of November. Plot size was 5m x 3m. A pre-sowing irrigation was given for proper germination and establishment. Remaining Irrigations were applied as and when required as per treatment recommendation. One irrigation in plots under I_2 treatment and two irrigations in plots under I_3 treatment

Email: smritikanasarkar12@gmail.com

were applied. Irrigation water depth (IW) was maintained 50 mm for each irrigation with the help of parshall flume. For irrigation scheduling, 'Climatological approach' was followed, which involved estimation of atmospheric evaporative demand by taking ratio between 'amount of irrigation water applied (mm)' to the 'cumulative pan evaporation (CPE) (mm)'. Upon the arrival of pre-determined CPE, irrigation was applied in respective plots. The crop was harvested at maturity i.e. in 3rd week of March and yield date was recorded. Total rainfall during the crop growth period was 10.4 and 11.1 mm in successive years of experiment, respectively. The mean minimum and maximum temperature of about 13.8-21.9°C and 26.6-34.9°C, respectively were recorded during the experiment. The mean relative humidity ranged from 33.6 to 95.9 per cent. The mean pan evaporation per day ranged for 1.3 to 3.2 mm. Soil moisture studies were done during the entire crop period starting from sowing to final harvesting of the crop. Soil moisture record and soil samples were collected from middle of each plot and space between crop rows corresponding to all treatments from 0 - 15, 15 - 30, 30 - 45 and 45 - 60 cm soil depths with the help of an auger at sowing, immediately before and 48 hours after giving irrigation of each irrigation and at the same time from Rainfed plots nearly about 15 days interval and finally at harvest to determine the total soil moisture used up by the crop. The soil samples were dried in the oven at 105° C for 72 hours to calculate the moisture content on gravimetric basis. Volumetric moisture content was then calculated by multiplying the respective bulk density with the gravimetric moisture content. Water-use efficiency (WUE) was calculated based on the yield of the crop per unit of water used. The oil content of the seed was determined by Soxhelt ether extraction method. The economic analysis of the experiment was carried out by taking into consideration the prevailing market prices (^{1} kg^{-1}) of inputs used and economic produce. The data recorded for different parameters were analysed with the help of analysis of variance (ANOVA) technique for a Split-plot design (Gomez and Gomez, 1984). The results are presented at 5% level of significance (P=0.05).

RESULTS AND DISCUSSION

Growth attributes and oil content

Different levels of irrigation and mulch practices had significant influence on plant height, dry matter accumulation (DMA), crop growth rate (CGR), relative growth rate (RGR) of linseed during both the years of experiment (Table-1). Treatment receiving irrigation at IW/CPE of 0.6 maintained its superiority by producing tallest plant of about 7.75 per cent higher height over irrigation at IW/CPE of 0.4 while the minimum height was recorded under rainfed condition. Irrigation had beneficial influence on plant growth might be attributed to rapid cell division and elongation in presence of adequate moisture as compared to relatively stressed plants under rainfed situation (Shamsi *et al*,. 2010). Among mulch practices, the maximum plant height was registered with the application of black polythene. Straw mulch @ 5 t ha^{-1} recorded about 4.24 per cent more plant height over water hyacinth @ 5 t ha^{-1}. Favourable influence of mulch over no mulch on plant height was also observed by Kalita *et al.* (2005). DMA of the crop was found to increase progressively with the advancement of crop growth and reached their maximum values at 120 days after sowing (DAS). DMA increased with the increasing levels of irrigation and reached at its maximum with irrigation applied at IW/CPE of 0.6. This is probably due to the fact that irrigation enhanced higher rate of photosynthesis resulting better accumulation of biomass as compared to moisture stress condition. Improvement in DMA in linseed with irrigation was also observed by Gabiana *et al.* (2005). Maximum DMA throughout the growth period was maintained when linseed was mulched with black polythene. Straw mulch @ 5 t ha^{-1} treatment recorded better performance than water hyacinth mulch @ 5 t ha^{-1} and the rate of increment were about 15.24, 4.77, 7.89 and 6.38 per cent in at different dates of taking observations. CGR of linseed was found to increase from its initial lower value at 30–60 DAS to higher at 60-90 DAS (the grand growth period) and then again decreased at 90-120 DAS. At 60 to 90 DAS irrigation at IW/CPE of 0.6 continued its superiority with 5.85 g m^{-2} day^{-1} CGR which was 21.34 and 43.10 per cent higher over the treatment receiving irrigation at IW/CPE of 0.4 and rainfed, respectively. Plants mulched with black polythene showed the maximum growth rate and was significantly superior. The next best performance was registered with the application of straw @ 5 t ha^{-1} and was followed by water hyacinth @ 5 t ha^{-1}. Increase in CGR with the increasing levels of irrigation under proper utilization of mulch was also stated by Yenpreddiwar *et al.* (2007). RGR of the crop was higher during 30 – 60 DAS and declined gradually at later stages of growth. At 60-90 DAS irrigation at IW/CPE of 0.4 registered higher RGR than other irrigation levels while mulch practices showed the same trend as noticed with other growth attributes. At 90-120 the reverse trend was observed where, rainfed crop without any mulch application showed better response. The reason behind such variation of RGR is due to the variation in DMA of the crop. Results revealed that, application of irrigation over no irrigation recorded higher oil content in seeds of linseed (Table 2). Oil content was highest (35.67%) when the crop was

Table 1: Effect of irrigation and mulch on growth attributes of linseed (mean over 2 years)

Treatments	Plant height	Dry matter accumulation (g m^{-2})				Crop growth rate (g m^{-2} day^{-1})			Relative growth rate (g g^{-1} day^{-1})		
		30 DAS	60 DAS	90 DAS	At harvest	30-60 DAS	60-90 DAS	90-120 DAS	30-60 DAS	60-90 DAS	90-120 DAS
Irrigation levels											
Rainfed	63.8400	7.1700	49.550	172.190	259.110	1.413	4.088	2.897	0.065	0.041	0.014
Irrigation at IW/CPE of 0.4	69.1500	7.7100	53.700	198.320	291.3300	1.533	4.821	3.100	0.065	0.045	0.013
Irrigation at IW/CPE of 0.6	74.5100	8.2000	58.750	234.260	327.870	1.685	5.850	3.120	0.066	0.044	0.011
SEm (±)	**0.1960**	**0.0300**	**0.124**	**1.012**	**1.113**	**0.007**	**0.0150**	**0.016**	**0.002**	**0.0005**	**0.0003**
LSD(0.05)	**0.584**	**0.091**	**0.370**	**3.030**	**3.331**	**0.021**	**0.0460**	**0.049**	**NS**	**0.0014**	**0.0008**
Mulch treatments											
No mulch	65.10	6.49	50.57	177.37	264.82	1.470	4.226	2.915	0.0684	0.0417	0.0135
Water hyacinth @ 5 t ha^{-1}	67.64	7.15	52.65	195.46	285.24	1.517	4.760	2.993	0.0665	0.0435	0.0127
Straw mulch @ 5 t ha^{-1}	70.51	8.24	55.16	210.88	303.44	1.564	5.191	3.086	0.0634	0.0445	0.0122
Black polythene	73.42	8.89	57.62	222.66	317.58	1.624	5.502	3.164	0.0623	0.0449	0.0120
SEm (±)	**0.201**	**0.032**	**0.148**	**1.110**	**1.224**	**0.005**	**0.019**	**0.018**	**0.0023**	**0.0004**	**0.0001**
LSD(0.05)	**0.601**	**0.097**	**0.447**	**3.328**	**3.670**	**0.016**	**0.058**	**0.052**	**NS**	**0.0010**	**0.0003**

Table 2: Effect of irrigation and mulch on oil content, yield and economics of linseed (mean over 2 years)

Treatments	Oil content (%)	Seed yield (kg ha^{-1})	Straw yield (t ha^{-1})	HI (%)	Gross return (Rs. 10^3 ha^{-1})	Net Returns (Rs. 10^3 ha^{-1})	Benefit : cost ratio	WUE (kg ha^{-1} mm^{-1})	WEE(Kg ha^{-1} mm^{-1})
Irrigation levels									
Rainfed	34.72	607.00	2.610	18.88	21.9	7.47	0.52	3.339	
Irrigation at IW/CPE of 0.4	35.18	669.01	2.793	19.35	24.1	8.62	0.56	3.115	13.39
Irrigation at IW/CPE of 0.6	35.67	713.99	2.965	19.42	25.7	9.58	0.60	3.017	7.15
SEm (±)	**0.061**	**1.088**	**0.007**	**0.099**	-	-	-	-	-
LSD(0.05)	**0.184**	**3.267**	**0.023**	**0.292**	-	-	-	-	-
Mulch treatments									
No mulch	34.57	616.60	2.552	19.44	22.2	7.57	0.52	2.863	9.58
Water hyacinth @ 5 t ha^{-1}	35.06	650.85	2.729	19.26	23.5	8.30	0.55	3.082	10.10
Straw mulch @ 5 t ha^{-1}	35.39	678.26	2.890	19.02	24.5	8.87	0.57	3.263	10.44
Black polythene	35.73	707.62	2.987	19.16	25.5	9.48	0.59	3.420	10.94
SEm (±)	**0.065**	**1.362**	**0.007**	**0.128**	-	-	-	-	-
LSD(0.05)	**0.195**	**4.089**	**0.019**	**NS**	-	-	-	-	-

Table 3: Effect of irrigation and mulch on nutrient content and uptake of linseed (mean over 2 years)

Treatments	Nutrient content (%)						Nutrient Uptake (Kg ha^{-1})					
	N		P		K		N		P		K	
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
Irrigation levels												
Rainfed	2.088	0.531	0.526	0.141	0.859	1.832	12.691	13.878	3.193	3.702	5.222	47.737
Irrigation at IW/CPE of 0.4	2.164	0.594	0.559	0.154	0.894	1.898	14.491	16.633	3.748	4.335	5.990	53.136
Irrigation at IW/CPE of 0.6	2.138	0.575	0.572	0.167	0.921	1.917	15.284	17.114	4.092	4.976	6.581	56.989
SEm (±)	**0.004**	**0.003**	**0.002**	**0.001**	**0.002**	**0.003**	**0.133**	**0.058**	**0.032**	**0.047**	**0.005**	**0.305**
LSD(0.05)	**0.013**	**0.009**	**0.007**	**0.003**	**0.007**	**0.010**	**0.394**	**0.179**	**0.089**	**0.143**	**0.016**	**0.916**
Mulch treatments												
No mulch	2.035	0.522	0.524	0.131	0.856	1.784	12.555	13.325	3.234	3.350	5.288	45.541
Water hyacinth @ 5 t ha^{-1}	2.105	0.557	0.546	0.147	0.880	1.850	13.710	15.198	3.564	4.013	5.737	50.525
Straw mulch @ 5 t ha^{-1}	2.203	0.598	0.570	0.167	0.911	1.939	14.952	17.323	3.877	4.854	6.191	56.125
Black polythene	2.175	0.590	0.569	0.171	0.918	1.956	15.405	17.652	4.037	5.134	6.508	58.293
SEm (±)	**0.003**	**0.003**	**0.002**	**0.003**	**0.001**	**0.004**	**0.125**	**0.076**	**0.040**	**0.062**	**0.006**	**0.411**
LSD(0.05)	**0.010**	**0.010**	**0.005**	**0.010**	**0.004**	**0.012**	**0.379**	**0.229**	**0.117**	**0.187**	**0.017**	**1.239**

irrigated at IW/CPE of 0.6 and was followed by the treatment receiving irrigation at IW/CPE of 0.4 producing 1.39 per cent less oil in seeds but about 1.32 per cent more oil over the treatment receiving no irrigation. Singh *et al.* (1997) also reported that irrigation increased oil yield of linseed. Mulched plants produced higher oil content in seed over no mulched one and the maximum was exhibited with Black polythene followed by straw mulch @ 5 t ha^{-1}.

Yield

Seed and straw yield of linseed increased significantly with irrigation application over rainfed (Table 2). The mean seed yield increased by 10.22 and 17.63 per cent over rainfed owing to application of irrigation at IW/CPE of 0.4 and IW/CPE of 0.6, respectively. The corresponding increases in straw yield were 7.01 and 13.60 per cent. The favourable effect of irrigation on growth and yield attributes of linseed was mainly responsible for higher grain and straw yields. The results confirm the findings of Lodhi *et al.* (2007). Different mulch treatments imparted a significant increase in grain and straw yield over no mulch. The highest grain and straw yields were recorded with black polythene, which registered 14.76 and 17.05 per cent higher grain and straw yield over no mulch. The next best performance was obtained with straw mulch @ 5 t ha^{-1} and was followed by water hyacinth @ 5 t ha^{-1}. The increase in yield owing to mulch application may be ascribed to improved growth and yield attributes and yield is directly related to these attributes. Kalita *et al.* (2005) confirm the findings. Harvest index is the indicator of seed yield per cent of the biological yield in the respective treatments. However, with mulch application there was no significant difference in harvest index of linseed. Application of irrigation at IW/CPE of 0.6 increased seed yield, ultimately results high harvest index Gopalakrishna *et al.* (1996).

Economics

Each successive increment in irrigation number increased the net return and benefit cost ratio (BCR) (Table 2). Significantly highest net return and BCR were earned with irrigation at IW/CPE of 0.6, which have proved more remunerative than the other levels of irrigation. It was closely followed by the irrigation applied at IW/CPE of 0.4. From mulch application perspective, the maximum net return and BCR were worked out with black polythene followed by straw mulch @ 5 t ha^{-1}. However, no mulch showed the minimum net return and BCR due to lower seed and straw yield. The favourable effect of both irrigation and mulch for earning higher return was also observed by Thenua *et al*. (2010).

Nutrient content and uptake

Both irrigation and mulch had significant influence on nutrient contents (N, P and K) and uptake in seed and straw over control (Table 3). Higher N content was observed with the application of irrigation at IW/CPE of 0.4 being which was 3.64 and 11.86 per cent in seed and straw respectively over rainfed linseed. P and K content were higher at IW/CPE of 0.6. Increase in nutrient uptake (N, P and K) due to irrigation at IW/CPE of 0.6 was 20.43, 28.16 and 26.02 per cent in seed as well as 23.32, 34.41 and 19.38 per cent higher in straw than rainfed. The second higher N, P and K uptake by seed and straw was recorded with irrigation at IW/CPE of 0.4. Positive influence of irrigation on nutrient uptake in chickpea was noticed by Abraham *et al*. (2010). Considering different mulch treatments, straw mulch @ 5 t ha^{-1} recorded highest N content in both seed and straw and highest P in seed only over other mulch treatments. Black polythene showed highest P in straw and K in both seed and straw. It was followed by straw mulch @ 5 t ha^{-1}. Application of black polythene topped the list by recording remarkably higher N, P and K uptake by both grain and straw over other mulch treatments. Straw mulch @ 5 t ha^{-1} recorded higher nutrient (N, P and K) uptake, percent increase being 9.06, 8.78 and 7.91 in seed and 13.98, 20.96 and 11.08 in straw than water hyacinth @ 5 t ha^{-1}. Higher nutrient uptake due to mulch application in mustard was also stated by Tetarwal *et al.* (2013).

***Water use efficiency and* water expanse efficiency**

Water use efficiency (WUE) was highest (3.339 kg ha^{-1} mm^{-1}) at rainfed treatment mainly due to greater increase in seed yield as compared to increase in quantity of water used (Table 2). Linseed irrigated at IW/CPE of 0.4 recorded next higher WUE (3.115 kg ha^{-1} mm^{-1}) and was followed by the treatment receiving irrigation at IW/CPE of 0.6 (3.017 kg ha^{-1} mm^{-1}). Irrigation applied at IW/CPE of 0.04 showed higher water expanse efficiency (WEE) as compared to IW/CPE of 0.6. The findings are in conformity with those of Patel *et al*. (2007) in fennel. The highest WUE and WEE were recorded with black polythene mulch. The next best performance was observed with straw mulch @ 5 t ha^{-1} and was followed by water hyacinth @ 5 t ha^{-1}. The lowest WUE and WEE were obtained in no mulch treatment. This was mainly due to greater control in water loss as evaporation and higher seed yield in mulched treatment. These results corroborate the findings of Mehta *et al*. (2010).

Thus, it can be inferred that for increasing growth, yield and profitability of linseed both irrigation and mulch in combination is viable. Mulch provides great effort in improving water use efficiency. Treatment combination receiving irrigation at IW/CPE of 0.6 along with black polythene mulch maintained its superiority throughout the crop growth period on various aspects.

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