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RESEARCH ARTICLE

Effect of sowing environments on radiation interception and growing degree days in linseed (*Linum usitatissimum* L.)

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SUMMARY

The field experiment was laid out in Split Plot Design with three replications. The treatments consisted of 6 dates of sowing D_1: 40th MW, D_2: 41st MW, D_3: 42nd MW, D_4: 43rd MW D_5: 44th MW and D_6: 45th MW as main plot treatment and 3 cultivars V_1: Kiran V_2: Garima V_3: RLC-4 as sub plot treatment at college of Agriculture latur during *Rabi* season. The data presented revealed that duration required for emergence ranged from 6 days under different date of sowing in different cultivars tested whereas in P_3 (branching to flowering) and P_4 (flowering to capsule formation) which are critical growth stages from the seed yield point of view, ranged from 17 to 22 days and 22 to 27 days, respectively. The data revealed that, the total heat requirement during the crop life cycle ranged from 1221 ^{0}Cd to the 1514 ^{0}Cd. The heat load, reported a decreasing trend as the sowing time was delayed. Decreasing trends in accumulated growing degree-days was observed with successive delay in sowing of all the cultivars. The data further reveled that the heat requirement was almost double, during reproductive growth stages than the vegetative growth stages. As regards the total thermal requirement of cv. KIRAN, it required maximum thermal units as 1514 ^{0}Cd in first (D_1) date of sowing at MW 40. This cultivar recorded the lowest thermal requirement as 1334 ^{0}Cd in sixth (D_6) date of sowing at MW 45. Cultivar Garima required maximum thermal units as 1270 ^{0}Cd when linseed crop was sown in MW 40. This cultivar recorded the lowest thermal units as 1334 ^{0}Cd under (D_6) treatment (MW 45). Cultivar RLC-4 recorded the highest thermal requirement of 1416 ^{0}Cd in (D_1) MW 40. This cultivar recorded the lowest thermal unit as 1221 ^{0}Cd under sixth (D_6) date of sowing at MW 45. The photosynthetic active radiation (PAR) recorded periodically in different treatments data revealed that at 30 DAS the minimum and same value were recorded in almost all the treatments. However, as the crop growth advanced the absorption rate increased abruptly, in all the treatments except D_4 during the period of 40-50 DAS. The increase in absorbed PAR was almost higher in treatments D_1 and D_2, which persisted up to 70 DAS. Thereafter a gradual decreased in PAR absorption was noticed till 110 DAS *i.e.*, physiological maturity. However in treatment D_4 the abrupt decrease during 90 to 100 DAS was also noticed. The increased PAR from 40 DAS to 70 DAS indicated a proper source sink relationship because of proper canopy development.

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Linseed (*Linum usitatissimum* L.) can grow on all types of soil, where sufficient moisture is available. However, it does better in clayey soil having more water retention capacity when grown under stored soil moisture. The linseed crop does well under moderate cold but the fibre crop grow best in cool moist climate. It requires dry weather condition during maturity. Linseed crop require moderate or cool temperature during the vegetative development stage. This crop thrives well in the temperature ranges of 25^0 C to 30^0 C during germination and about 15^0 C to 20^0 C during seed formation *i.e.*, reproductive growth stage. It is reported that high temperature above 32^0 C accompanied with drought during flowering reduced yield, oil content and the quality of crop. Linseed may be damaged or destroyed at a temperature between -8^0 C and 3^0 C at seedling stage. However, during other stages plant may survive at a temperature of -9^0 C or even lower linseed is fairly resistant to drought and grows well in areas receiving annual rainfall of 450-750 mm (Prasad, 2004). With these objectives in mind, the study was planned in field condition.

MATERIAL AND METHODS

The field experiment was laid out in Split Plot Design with three replications. The treatments consisted of 6 dates of sowing D_1: 40th MW, D_2: 41st MW, D_3: 42nd MW, D_4: 43rd MW D_5: 44th MW and D_6: 45th MW as main plot treatment and 3 cultivars V_1: Kiran V_2: Garima V_3: RLC-4 as sub plot treatment at college of Agriculture latur during *Rabi* season.

Estimation of growing degree days (GDD) :

The growing degree days (GDD) were worked out by considering the base temperature of 10^0 C. The total growing degree days (GDD) for different phenophases were estimated by using the following equation :

$$\text{Accumulated GDD} = \sum_{ds}^{dh}[(T_{max} + T_{min})/2] - Tb$$

where,

GDD = Growing degree days (^{0}Cd) ,

T_{max} = Daily maximum temperature (^{0}C)

T_{min} = Daily minimum temperature (^{0}C)

Tb = Base temperature (^{0}C)

ds = Date of emergence or starting date of any phenophase of interest

dh = Date of harvest or the end of the phenophase of interest

Estimation of absorbed photosynthetic active radiation (PAR) :

Absorbed PAR was calculated by following formulae:

$$a = i - (r + t)$$

where, a = absorbed radiation, i = incident radiation r= reflected radiation, t = transmitted radiation.

The data recorded were statistically analyzed by using technique of analysis of variance (Fisher, 1937) and significance was determined as given by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Phenological stages :

The data presented in Table 1 revealed that duration required for emergence ranged from 6 days under different date of sowing in different cultivars tasted whereas in P_3 (branching to flowering) and P_4 (flowering to capsule formation) which are critical growth stages from the seed yield point of view, ranged from 17 to 22 days and 22 to 27 days, respectively. The duration during

Table 1 : Mean number of days required to attain various phenophases and their duration in linseed cultivars Kiran, Garima and RLC-4

Growth stages	Kiran (V_1)						Garima (V_2)						RLC-4 (V_3)					
	D_1	D_2	D_3	D_4	D_5	D_6	D_1	D_2	D_3	D_4	D_5	D_6	D_1	D_2	D_3	D_4	D_5	D_6
P_1	9	10	11	11	11	11	8	9	9	10	9	9	6	7	7	8	7	7
P_2	25	24	23	24	23	22	22	21	22	21	20	20	21	20	19	19	19	20
P_3	22	20	19	19	19	19	19	19	17	18	18	18	18	18	17	17	17	18
P_4	25	26	24	23	22	23	25	25	24	24	24	25	27	25	24	25	24	25
P_5	26	25	24	25	26	25	26	25	25	25	25	23	26	24	23	25	24	22
P_6	16	16	15	14	14	15	15	15	14	14	14	15	13	14	15	13	15	14
Total	123	119	116	116	115	115	115	114	111	112	110	110	111	108	105	107	106	106

P_1 - sowing to emergence; P_3 - Branching to flowering; P_5 - Capsule formation to capsule development
P_2 - Emergence to branching; P_4 - Flowering to capsule formation; P_6 - Capsule development to maturity

these growth stages are well receptive of photosynthetic active radiation, providing a better source-sink relationship. The higher leaf area during reproductive stage in the crop sown in MW 40 seems to have helped in maximum PAR absorption.

Growing degree days (^{0}Cd) :

The data regarding heat load available to the crop during different phenophages under different treatment imposed are presented in Table 2. The data revealed that, the total heat requirement during the crop life cycle ranged from 1221 ^{0}Cd to the 1514 ^{0}Cd. The heat load, reported a decreasing trend as the sowing time was delayed. Decreasing trends in accumulated growing degree-days was observed with successive delay in sowing of all the cultivars. These results are in conformation to the findings of Chand *et al.* (1995). The data further reveled that the heat requirement was almost double, during reproductive growth stages than the vegetative growth stages.

Cultivar Kiran:

As regards the total thermal requirement of cv. KIRAN, it required maximum thermal units as 1514 ^{0}Cd in first (D_1) date of sowing at MW 40. This cultivar recorded the lowest thermal requirement as 1334 ^{0}Cd in sixth (D_6) date of sowing at MW 45 (Table 2).

Cultivar Garima:

Cultivar Garima required maximum thermal units as 1432 ^{0}Cd when linseed crop was sown in MW 40. This cultivar recorded the lowest thermal units as 1270 ^{0}Cd under (D_6) treatment (MW 45) (Table 2).

Cultivar RLC-4:

Cultivar RLC-4 recorded the highest thermal

Table 2 : Growing degree days (^{0}Cd) requirement of linseed cv. KIRAN, GARIMA and RLC-4 under different dates of Sowing

Growth stages	Kiran (V_1)						Garima (V_2)						RLC-4 (V_3)					
	D_1	D_2	D_3	D_4	D_5	D_6	D_1	D_2	D_3	D_4	D_5	D_6	D_1	D_2	D_3	D_4	D_5	D_6
P_1	136	162	159	159	168	162	122	162	130	144	137	138	91	102	103	114	104	110
P_2	372	333	323	322	299	270	322	281	316	288	280	250	305	299	281	270	261	253
P_3	283	246	227	202	214	215	256	239	199	218	216	201	257	217	213	208	204	204
P_4	284	277	269	260	251	269	295	284	272	275	273	286	323	291	272	391	279	284
P_5	282	269	250	260	267	252	297	282	275	270	269	232	292	274	260	266	252	225
P_6	157	138	153	142	149	176	141	128	138	142	141	162	159	151	151	128	150	145
Total	1514	1424	1381	1345	1348	1334	1432	1375	1330	1337	1306	1270	1416	1335	1280	1275	1250	1221

P_1 - sowing to emergence; P_2 - Emergence to branching; P_3 - Branching to flowering
P_4 - Flowering to capsule formation; P_5 - Capsule formation to capsule development; P_6 - Capsule development to maturity

Table 3 : Periodic values of mean absorbed radiation (Watt m^{-2})

Date of sowing	30	40	50	60	70	80	90	100	110
Treatments									
D_1 (MW 40)	87	105	184	187	243	190	150	103	91
D_2 (MW 41)	80	98	147	159	178	177	132	103	78
D_3 (MW 42)	83	96	151	151	173	151	116	80	66
D_4 (MW 43)	84	105	121	156	179	162	129	66	50
D_5 (MW 44)	84	102	152	154	158	116	102	47	48
D_6 (MW 45)	78	103	160	165	154	115	102	51	62

Table 4: Periodic values of mean incident radiation (Wm^{-2})

Date of sowing	30	40	50	60	70	80	90	100	110
Treatments									
D_1 (MW 40)	302	313	303	173	279	279	311	311	307
D_2 (MW 41)	253	261	285	267	313	311	280	313	325
D_3 (MW 42)	286	285	301	311	273	284	312	325	337
D_4 (MW 43)	265	240	313	316	314	289	314	308	325
D_5 (MW 44)	274	260	328	321	280	313	325	325	324
D_6 (MW 45)	223	239	318	323	273	313	318	325	324

requirement of 1416 ^{0}Cd in (D_1) MW 40. This cultivar recorded the lowest thermal unit as 1221 ^{0}Cd under sixth (D_6) date of sowing at MW 45 (Table 2).

Radiation study:

The photosynthetic active radiation (PAR) recorded periodically in different treatments imposed were measured with the Accupar Inceptometer. The incident PAR, transmitted PAR and reflected PAR were measured at an interval of 10 days, starting from 30 DAS. From the data, the absorbed PAR were estimated using the equation, a + r + t = I, where I is the incident PAR, a is the Absorbed PAR, r is the reflected PAR and t is the transmitted PAR. The results on this aspect are presented in Table 3 to 6. The data revealed that at 30 DAS the minimum and same value were recorded in almost all the treatments. However, as the crop growth advanced the absorption rate increased abruptly, in all the treatments except D_4 during the period of 40-50 DAS. The increase in absorbed PAR was almost higher in treatments D_1 and D_2, which persisted up to 70 DAS. Thereafter, a gradual decreased in PAR absorption was noticed till 110 DAS *i.e.*, physiological maturity. However, in treatment D_4 the abrupt decrease during 90

Table 5 : Periodic values of mean transmitted radiation (Wm^{-2})

Date of sowing	30	40	50	60	70	80	90	100	110
Treatments									
D_1 (MW 40)	193	189	101	75	105	173	157	186	197
D_2 (MW 41)	154	146	122	98	120	115	111	188	123
D_3 (MW 42)	183	171	134	143	98	115	176	224	245
D_4 (MW 43)	150	119	176	143	115	111	162	200	254
D_5 (MW 44)	171	140	168	148	102	176	200	254	252
D_6 (MW 45)	125	119	141	136	93	177	254	254	241

Table 6: Periodic values of mean reflected radiation (W m^{-2})

Date of sowing	30	40	50	60	70	80	90	100	110
Treatments									
D_1 (MW 40)	21	19	18	10	14	19	20	21	17
D_2 (MW 41)	18	17	15	9	20	19	22	22	23
D_3 (MW 42)	19	17	19	17	23	18	21	20	20
D_4 (MW 43)	18	16	17	15	19	17	23	19	21
D_5 (MW 44)	15	17	19	18	20	21	22	22	23
D_6 (MW 45)	19	16	17	23	23	21	19	19	21

Table 7 : Mean seed yield (kg ha^{-1}), straw yield (kg ha^{-1}), total biomass (kg ha^{-1}), as influenced by various treatments

Treatments	Seed yield (kg/ha)	Straw yield (kg/ha)	Total biomass (kg/ha)
Date of sowing			
D_1 (MW 40)	889	2109	2998
D_2 (MW 41)	823	2999	2822
D_3 (MW 42)	654	1999	2653
D_4 (MW 43)	543	1540	2083
D_5 (MW 44)	473	1582	2055
D_6 (MW 45)	334	979	1313
S.E. ±	7.33	10.48	12.43
C.D. (P=0.05)	23.12	33.05	39.19
Cultivars			
V_1 –Kiran	613	1619	2232
V_2- Garima	656	1773	2429
V_3- RLC-4	588	1712	2300
S.E. ±	6.4	6.8	6.5
C.D. (P=0.05)	19.0	19.92	19.02

to 100 DAS was also noticed. The increased PAR from 40 DAS to 70 DAS indicated a proper source sink relationship because of proper canopy development. The decrease in PAR absorption after 70 DAS may be due to senescence of leaves in this period. The higher PAR absorption in treatments D_1 and D_2 seems to have helped in ideal photosynthesis process.

Yield :

The data regarding yield *viz.,* seed yield, straw yield, and total biomass are presented in Table 7.

Seed yield (kg ha^{-1}) :

The data presented in Table 7 revealed that mean seed yield (kg ha^{-1}) was influenced significantly by various dates of sowing and cultivars.

Date of sowing :

The mean seed yield (kg^{-1} ha) was found significantly higher in first (D_1) at MW 40 over other date of sowing treatments and was significantly superior. Similar trends were also recorded by Verma and Pathak (1993) and Sharma *et al*. (1995).

Cultivars :

The effect of cultivars on seed yield ha^{-1} revealed that cv. GARIMA produced significantly higher seed yield than other cultivars. Similar findings were also reporded by Verma and Pathak (1993), Dhaliwal *et al.* (2011) and Sharma *et al.* (2011).

Straw yield :

Data presented in Table 7 revealed that the mean straw yield of linseed was in influenced significantly by different treatments.

Date of sowing :

The data presented in Table 7 revealed that second (D_2) date of sowing at MW 41 gave highest yield of 2999 kg ha^{-1} and was significantly superior than other date of sowing treatments. The second and third highest position in respect of grain yield of linseed was acquired by D_2 and D_3 treatment at MW 41 and MW 42. Above results are in confirmation with that of Dixit *et al.* (1994). The significantly lowest grain yield of linseed was acquired by D_6 treatment at MW 45.

Cultivars :

The effect of cultivars on straw yield ha^{-1} presented in Table 7 revealed that cv. GARIMA gave significantly higher straw yield than other cultivars.

Biological yield (kg ha^{-1}) :

The data presented in Table 7 revealed that mean biological yield was influenced significantly by different treatments.

Date of sowing :

The data presented in Table 7 revealed that biological yield was found significantly more in first (D_1) date of sowing at MW 40 than other dates of sowing. The similar findings have been reported by Dixit *et al.* (1994); Apotikar *et al.* (2012) and Andhale *et al.* (2012).

Cultivars :

The effect of cultivars on biological yield ha^{-1} revealed that cv. GARIMA was significantly superior than other cultivars.

Conclusion :

– Sowing of linseed cv. GARIMA with first date of sowing MW 41 was found advantageous in recording more seed yield.
– Cultivar Kiran, Garima and RLC-4 required 115 to 123, 110 to 115 and 105 to 111 days for maturity, respectively.
– Cultivar Kiran, Garima and RLC-4 required 1514-1334 ^{0}Cd, 1432-1270 ^{0}Cd and 1416-1221 ^{0}Cd growing degree-days, respectively.
– The higher canopy development helped in higher PAR absorption, which increased up to 70 days and there after declined due to senescence of leaves.

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