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Growth and quality parameter of safflower as influenced by different row proportion in intercropping system of safflower (*Carthamus tincorius* L.) and linseed (*Linum usitatissimum* L.) under Rainfed condition

Karale Gangadhar, SA Biradar, BK Desai, Ajithkumar K and Rajanna

Abstract
A field experiment was conducted to study the 'Growth and quality parameter of safflower as influenced by different row proportion in intercropping system of safflower (*Carthamus tincorius* L.) and linseed (*Linum usitatissimum* L.) under Rainfed condition' during 2015-16 at the Main Agricultural Research Station, Raichur with Randomized Complete Block Design with 7 treatments replicated four times. safflower (cv. S-144) and linseed (cv. NL-115) were intercropped in 1:1, 1:2, 2:1 and 2:2 row proportions at 30 cm rows each and both crops were grown as sole crops at their recommended row spacing (60 cm for safflower and 30 cm for linseed), along with these mixed cropping of safflower and linseed were also included. Results revealed that significantly higher oil yield and oil content of safflower were recorded with their pure stands of the crops. But as when compare with different intercropping system the highest oil yield of safflower was significantly recorded in Safflower + linseed (1:2) 30 cm rows (374 kg ha^{-1}) and the highest oil content was significantly recorded in Safflower + linseed (1:1) 30 cm rows (30 per cent). However, safflower + linseed (1:2) row proportion recorded significantly higher safflower equivalent yield (1686 kg ha^{-1}) and LER (1.20) followed by safflower + linseed in 1:1 row proportion (1450 kg ha^{-1} and 1.03, respectively) and sole linseed (1433 kg ha^{-1} and 1.0, respectively).

Keywords: intercropping system, oil content, oil yield, safflower, linseed, rainfed condition

1. Introduction
The interest for the introduction of alternative crops in the rotation system of winter cereals has been increased worldwide the last years. Safflower (*Carthamus tinctorius* L.) is one of the most important oilseed crops of the semi-arid regions belonging to the family Asteraceae (Compositae). The genus Carthamus is composed of about 25 species that are indigenous to the Mediterranean region and distributed from Spain to North America, West Asia, India. Safflower is one of the world's oldest crops, and the seeds have been found in Egyptian tombs over 4,000 years old and its use was recorded in China approximately 2200 years ago. Based on the closely related wild species, safflower was believed to have originated in an area bound by the Eastern Mediterranean and Persian Gulf, encompassing Southern parts of former USSR, Western Iran, Iraq, Syria, Southern Turkey, Jordan and Israel (Knowles, 1969). Presently, safflower is cultivated on a commercial scale in India, USA, Mexico, Ethiopia, Australia, China, Argentina and Russia and to a limited extent in Pakistan, Italy, Spain, Portugal and Iran.

The cultivated safflower (*Carthamus. tinctorius* L.) was believed to have originated from *C. lanatus* and *C. oxyacantha* (Weiss, 1971; Knowles and Schank, 1964). India is the largest safflower producing country in the world and ranks first in the world with an area of 9.55 lakh ha with a production of 8.09 lakh tonne and productivity of 846 kg ha^{-1} (2012-13 to 2014-15). In India, Maharashtra is leading in terms of acreage and production followed by Karnataka, Andhra Pradesh and Orissa (2014-2015).

Safflower yield and oil components may be affected by many factors, such as genotype, ecology, morphology, physiology and fertilization (Cosge *et al*., 2007) [6]. The time of sowing has great impact on safflower oil properties (Senkal *et al*., 2016) [25]. Several studies report that sowing safflower in autumn may lead to a significant increase in seed yield (Koutroubas *et al*., 2004; Yau, 2007; Golzarfar *et al*., 2012) [18, 32, 10]. Thus, due to the low fertility of tropical soils, low volume of scientific information on the subject and the hypothesis that safflower response to basic fertilization is dependent on sowing seasons, the aim of this study was to evaluate the effects of different fertilizer rates on yield components, seed yield and safflower oil content in

two growing seasons.

2. Materials and Methods

A field experiment was conducted during *rabi* of 2015-16 at Main Agricultural Research Station, University of Agricultural Science, Raichur, Karnataka on medium black soil under rainfed agro eco-system. The soil was low in organic carbon (0.53 g kg^{-1}), available nitrogen (115.28 kg ha^{-1}), high phosphorus (59.21 kg ha^{-1}) and high potassium (473.55kg ha^{-1}), with pH of slight alkaline (7.78) (Table 1).

Table 1: Physical and chemical properties of soil of the experimental site.

Particulars	Value obtained	Method adopted
I. Physical properties		
1. Fine sand (%)	7.20	
2. Silt (%)	28.60	
3. Clay (%)	64.20	
II. Chemical properties		
1. Soil pH (1:2.5)	7.78	pH meter (Piper, 1966)
2. Electrical conductivity (ds m^{-1})	0.21	Conductivity bridge (Jackson, 1967)
3. Organic carbon (%)	0.53	Wet oxidation method (Jackson, 1967)
4. Available nitrogen (kg ha^{-1})	115.28	Alkaline permanganate method (Subbaiah and Asija, 1956)
5. Available phosphorus (kg ha^{-1})	59.21	Olsen's method (Jackson, 1967)
6. Available potassium (kg ha^{-1})	473.55	Flame photometry method (Jackson, 1967)

Safflower (Cv. S-144) and linseed (Cv. NL-115) were intercropped in 1:1 and 1:2 row proportions at 30 cm rows and both crops were grown as sole crop at their recommended row spacing (45 cm for safflower and 30 cm for linseed), along with these treatments mixed cropping of safflower and linseed were also included. The experiment was laid out in randomized complete block design and replicated thrice. Both the crops were sown simultaneously and recommended dose of fertilizer were applied to sole crops and both the crops in intercropping system, based on the percent population of respective crops at the time of. The crops were sown as per the row proportions and spacing during second fortnight of October. The rainfall received during 2013-14 was 677.5 mm, while during cropping period was 95.5 mm (Table: 2). Oil content was measured by nuclear magnetic resonance (NMR) spectrophotometer against a standard reference sample and expressed in percentage (Anon., 1975) [2].

The oil yield was calculated by using following formula

$$\text{Oil yield (kg ha}^{-1}\text{)} = \frac{\text{Oil content (\%)}}{100} \times \text{Seed yield (kg ha}^{-1}\text{)}$$

The safflower yield was computed in terms of sorghum equivalent yield, gross returns as well as B:C to assess the system productivity and viability.

Table 2: Monthly meteorological data for the experimental year 2015-16 Meteorological Observatory, Main Agricultural Research Station, University of Agricultural Sciences, Raichur.

Month	Rainfall (mm)		Temperature (°C)				Relative humidity (%)	
			Mean maximum		Mean minimum			
	1932-2014	2015-16	1932-2014	2015-16	1932-2014	2015-16	1932-2014	2015-16
April	70.7	114.2	39.9	37.3	22.6	24.4	77.0	68.0
May	71.5	18.7	39.7	39.9	22.5	26.8	80.0	66.0
June	182.7	38.7	35.3	36.3	22.3	24.9	82.0	77.0
July	62.5	42.0	33.4	36.3	20.5	24.6	79.0	77.0
August	21.2	51.4	32.9	34.6	19.1	24.3	79.0	80.0
September	4.0	316.6	32.2	39.1	16.2	23.4	76.0	88.0
October	1.2	65.4	31.5	33.4	16.8	23.0	77.0	80.0
November	1.1	2.0	31.3	31.9	18.5	21.1	62.0	79.0
December	44.3	2.2	30.5	32.0	22.6	18.4	56.0	83.0
January	13.0	1.4	31.3	31.2	24.4	17.7	53.0	75.0
February	42.9	0.0	32.5	35.5	25.3	21.6	60.0	62.0
March	113.8	24.9	36.5	37.9	23.3	22.7	79.0	66.0
Total	628.9	677.5	-		-		-	

3. Results and Discussion

3.1 Growth and yield parameter of safflower

i) Plant height (cm)

Plant height of safflower was influenced significantly due to intercropping with linseed in different row proportion at all the stages of crop growth except at 30 days after sowing (DAS). At 60 DAS, significantly higher plant height was recorded in sole safflower (74.40 cm) (Table: 1). However, it was on par with mixed cropping of safflower and linseed (69.80 cm) and safflower + linseed (1:1) (68.90 cm) (Table: 3). Significantly lower plant height was recorded in safflower + linseed (1:2) (56.59 cm) (Table: 3). Among various treatment combinations, significant difference in plant height was observed at 90 DAS. Safflower + linseed (1:1) (82.70 cm) recorded significantly higher plant height and it was on par with mixed cropping of safflower and linseed (79.40 cm) and safflower + linseed (2:1) (79.10 cm) (Table:3). Significantly lower plant height was recorded in safflower + linseed (2:2) (62.40 cm). At harvest, significant difference in plant height was observed. Safflower + linseed intercropping system (1:1) was recorded significantly higher plant height (82.74cm) and it was on par with mixed cropping of safflower and linseed (80.30 cm) and safflower + linseed (2:1) (80.20 cm) (Table:3). Significantly lower plant height was recorded in safflower + linseed (2:2) (63.20 cm). The lower plant height in 2:2 row proportion due to more inter competation

between two crops. The similar result was also reported by Patel and Patel, (1993) while studying effect of irrigation on growth, yield and water-use efficiency of safflower (*Carthamus tinctorius* L.).

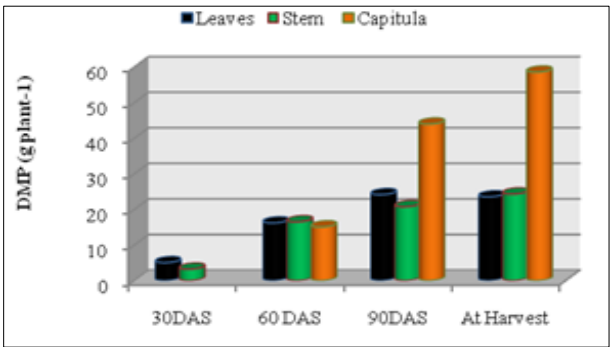
Table 3: Growth component of safflower as influenced by different row proportion in intercropping system of safflower and linseed under Rainfed condition.

Treatment	Growth components of safflower					
	Plant height (cm)			Dry matter production (g plant^{-1})		
	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest
T_1 – Safflower + linseed (1:1) 30 cm rows	68.90	82.70	82.74	47.87	89.13	106.51
T_2 – Safflower + linseed (1:2) 30 cm rows	56.59	67.20	67.24	54.27	93.99	111.66
T_3 – Safflower + linseed (2:1) 30 cm rows	57.60	79.10	80.20	51.22	92.40	108.79
T_4 – Safflower + linseed (2:2) 30 cm rows	64.60	62.40	63.20	45.23	86.48	96.86
T_5– Mixed cropping of safflower and linseed (100:20)	69.80	79.40	80.30	51.30	90.01	114.17
T_6 – Sole safflower (60 cm x 30 cm)	74.40	75.40	76.60	63.07	100.12	121.21
T_7 – Sole linseed (30 cm x 5 cm)	-	-	-	-	-	-
S.Em.±	2.44	2.43	2.30	1.51	1.86	3.30
C.D. (P=0.05)	7.51	7.50	7.09	4.66	5.73	10.17

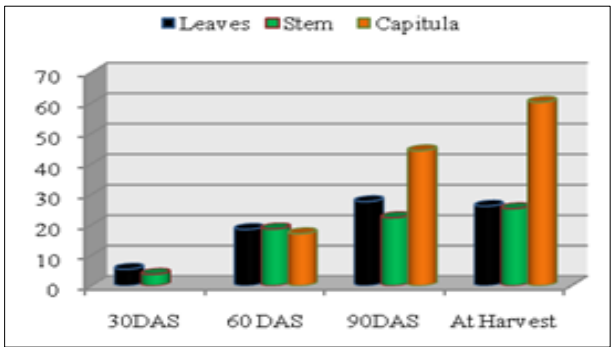
DAS days after sowing

ii) Dry matter production (g plant^{-1})

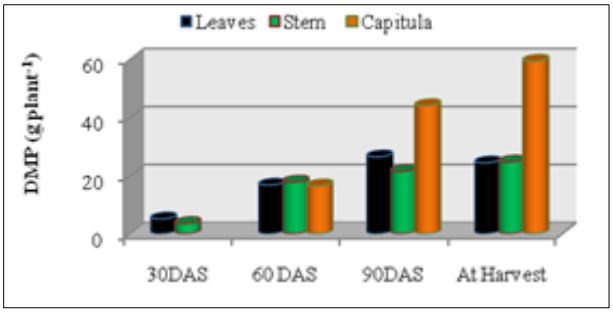
Dry matter production (DMP) of safflower differed significantly due to intercropping systems with different row proportion. At 30 DAS, significantly higher dry matter production was in sole safflower (10.27 g plant^{-1}) and among intercropping system, mixed cropping of safflower and linseed recorded higher (9.54 g plant^{-1}) (Table: 3). Significantly lowest DMP was recorded in safflower + linseed (2:2) (7.80 g plant^{-1}). At 60 DAS, significantly higher dry matter production was recorded in sole safflower (63.07 g plant^{-1}) and significantly lowest dry matter production was recorded in safflower + linseed (2:2) (45.23 g plant^{-1}). Among intercropping system safflower + linseed (1:2) (54.27 g plant^{-1}) (Table:3) recorded higher dry matter production. At 90 DAS, significantly higher DMP was recorded in sole safflower (100.12 g plant^{-1}) and significantly lower dry matter production was recorded in safflower + linseed (2:2) (86.48 g plant^{-1}). Among intercropping system safflower + linseed (1:2) (93.99 g plant^{-1}) recorded higher dry matter production. At harvest, significantly higher DMA was recorded in sole safflower (121.21 g plant^{-1}) and it was on par with mixed cropping of safflower and linseed (114.17 g plant^{-1}) and safflower + linseed (1:2) (111.66 g plant^{-1}) (Table:3) Fig:1. Significantly lower dry matter production was recorded in safflower + linseed (2:2) (96.86 g plant^{-1}). The dry matter production plant^{-1} alone does not reflect on the efficiency of cropping system but its greater partitioning into its reproductive parts is the real index of its effectiveness. The dry matter production and its accumulation in reproductive part depends upon photosynthetic ability of plant at various stages of growth and could be analyzed through leaf area and dry matter accumulation in leaf which in turn affect the photosynthetic ability, performance and yield of crop. Higher leaf area and leaf area index (LAI) lead to higher dry matter production by accumulating photosynthates, thus higher dry matter production contributed to higher yield plant^{-1}. Khapre *et al.* (1993) [14] reported that, leaf area being photosynthetic surface plays an important role in determining the total biomass production and quantity of photosynthates available for grain production.



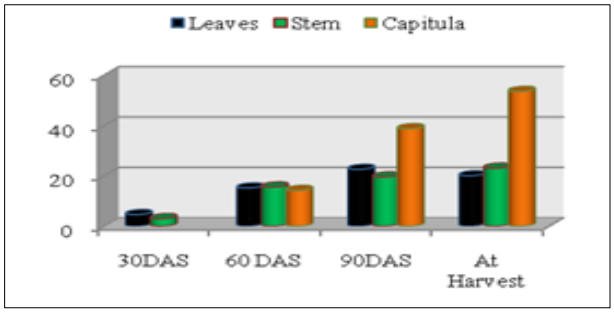
T_1- Safflower + linseed (1:1)



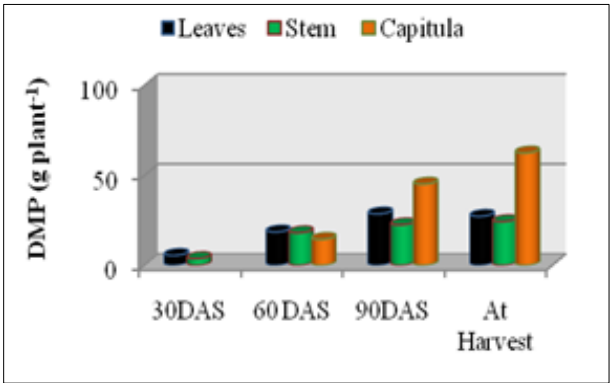
T_2- Safflower + linseed (1:2)



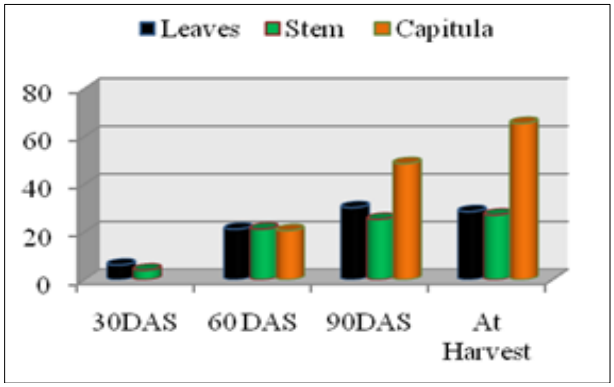
T_3- Safflower + linseed (2:1)



T_4- Safflower + linseed (2:2)



T5- Mixed cropping of safflower + linseed



T6- Sole safflower

Fig 1: Dry matter production in (leaves + stem + capitula) of safflower as influenced by varying row proportion in intercropping system of safflower and linseed

iii) Yield of safflower

Seed yield of safflower was influenced significantly due to intercropping systems with different row proportions and plant population. Sole safflower recorded significantly higher seed yield (1398 kg/ha) it was on par with mixed cropping of safflower and linseed (1298 kg/ha) and safflower + linseed (1:2) row proportion (1289 kg/ha) (Table: 4). Reduction in yield of safflower due to various intercropping combinations were in the order of safflower + linseed (1:2), safflower + linseed (1:1), safflower + linseed (2:2) and safflower + linseed (2:1) (Table: 4). Variation in the safflower yield might be due to several causes *viz*., variation in population levels, planting geometry, crop combinations, inter and intra species competition for light, moisture, nutrients, space *etc*. Superior values of yield in solitary stand of safflower might be attributed to competition free environment and optimum population level compared to intercropping treatments. Owing to higher population levels per unit area under intercropping systems resulted in inter and intra species competition for available resources. The results are in conformity with the findings of Manjithkumar *et al*. (2009) and Gobade *et al.* (2015) [9], where they, reported that yield of safflower and other *rabi* crops were always highest in sole cropping system as compared to other different intercropping system.

Table 4: Grain yield of safflower (kg ha^{-1}), Safflower equivalent yield (kg ha^{-1}), and economics as influenced by different row proportion and spacing

Treatment	Safflower grain yield (kg ha^{-1})	Safflower equivalent yield (kg ha^{-1})	Gross returns (ì ha^{-1})	Net returns (ì ha^{-1})	B:C
T1 – Safflower + linseed (1:1) 30 cm rows	1124	1450	36242	17638	1.94
T2 – Safflower + linseed (1:2) 30 cm rows	1289	1686	42158	23212	2.22
T3 – Safflower + linseed (2:1) 30 cm rows	755	1031	25770	8123	1.46
T4 – Safflower + linseed (2:2) 30 cm rows	852	1144	28596	11343	1.65
T5– Mixed cropping of safflower and linseed (100:20)	1298	1419	35483	18239	2.05
T6 – Sole safflower (60 cm x 30 cm)	1398	1398	34949	18979	2.18
T7 – Sole linseed (30 cm x 5 cm)	-	1433	35817	19376	2.17
S.Em.±	73	78	-	1093	0.11
C.D. (P=0.05)	224	240	-	3368	0.35

Seed yield of safflower under intercropping system was reduced to an extent of 85 per cent in 2:1, 64.10 per cent in 1:2, 24.37 per cent in 1:1, 8.45 per cent in 1:2 and 7.7 per cent in mixed cropping of safflower and linseed as compared to sole safflower. The reduction in yield was mainly due to varied plant population density. Similarly, Manjithkumar *et al*. (2009) also obtained lower yield of safflower under intercropping systems. The lower seed yield of safflower was produced when it was intercropped with linseed in 2:2 row ratios as compared to the rest of the treatment combinations. Comparable seed yield of safflower could be attributed to comparable performance of yield and growth component of safflower. Safflower when grown with linseed in mixed cropping system attributed to higher values of yield components *viz*., number of seed capitulum^{-1}, seed weight plant^{-1} and test weight. The other factor which indirectly influenced the seed yield are growth attribute *viz*., number of leaves per plant, leaf area, number of primary and secondary branches per plant, dry matter accumulation and its distribution in various plant parts. Thus, an attempt was made to identify and analyse the growth components which have led to the difference in the seed yield of safflower in light of observation made on yield components, dry matter distribution and growth attributes.

iv) Safflower equivalent yield

Crop equivalent yield is an important index for assessing the performance of different crops under a given circumstance. Based on the price structure, economic yield of component crops is converted into base crop yield *i.e.*, safflower equivalent yield (SEY). Safflower equivalent yield showed marked differences due to intercropping system at varying row proportion. The SEY was significantly higher in safflower + linseed in 1:2 (1686 kg ha^{-1}) as compared to sole crop of safflower followed by the safflower + linseed (1:1) (1450 kg ha^{-1}) (Table 4). The higher SEY in safflower + linseed (1:2) was due to higher yield obtained by both safflower and linseed and higher market price of linseed. These results are in conformity with the finding of Aladkatti *et al*. (2010) and Prasad *et al*. (1993) [23]. Gobade *et al.* (2015) [9] reported higher safflower equivalent yield (SEY) in sorghum + safflower (2:1) (2322 kg ha^{-1}) intercropping system compare to other row proportion. Lower SEY was recorded in safflower + linseed (2:1) (1031 kg ha^{-1}), safflower

+ linseed (2:2) (1144 kg ha^{-1}) and sole safflower (1398 kg ha^{-1}) (Table: 4). This might be due to less plant survival and absence of linseed in case of sole safflower. The productivity of a cropping system is mainly determined by the efficiency of the component crops in utilization of resources. The overall productivity of the intercropping of linseed with safflower relies on the main crop as well as compatibility with other crops.

Significantly higher LER was recorded when safflower intercropped with linseed in 1:2 row proportion (1.20) when compared to sole linseed (1.0) and sole safflower (1.0) (Table 2). Result shows that the highest LER value was achieved in safflower density of 8 plants row^{-1} and linseed densities of 16 plants/rows (LER=1.10) which is equal to 10 per cent increase in agricultural profitability compared to monocultures of two crops. The lower LER as 0.81 was obtained in six safflower and 16 linseed plants. Reduction of LER in higher densities can be due to inter-competition between linseed and safflower, which was confirmed by Hemayati *et al.* (2002) [11]. Similarly, Sarkar *et al.* (2003) [24] also reported higher LER under intercropping systems. Tanwar *et al*. (2011) [29] reported that intercropping systems of linseed with chickpea were found more LER and advantageous than sole cropping.

3.2 Quality parameter of safflower

i) Safflower oil yield (kg ha^{-1})

Oil yield is a combination of seed yield and oil content, so it was highly influenced by seed yield. Oil yield significantly differs due to intercropping system with different row proportion. Significantly higher oil yield was recorded in sole safflower (434 kg ha^{-1}) (Table: 5). Among safflower + linseed intercropping systems, higher oil yield was recorded in safflower mixed with linseed (390 kg ha^{-1}) followed by safflower + linseed (1:2) (374 kg ha^{-1}) (Table: 5) as compared to the rest of the treatment combinations. Significantly lower oil yield was noticed in safflower + linseed (2:1) (219 kg ha^{-1}) (Table: 5). This is mainly owing to less competition was noticed in Safflower + linseed 1:2 row proportion as a result luxurious growth of safflower were noticed which in turn increase the dry matter production and its accumulation in reproductive parts per plant at later stages of crop growth. Similar results were found by sharma *et al.* (1997) reported higher oil yield when sesamum intercropping with greengram. While sole safflower was recorded significantly higher oil yield (434 kg ha^{-1}) (Table: 5) this might be due to the higher dry matter production in turn lead to higher production of safflower oil yield and this is due no competition for resources from the sub-main crop. Similar result reported by Aladakatti *et al*, (2011) [1], while studying the effect of intercropping of oilseed crop on growth, yield and economics of cotton (*Gossipium Hirsutum*) under rainfed condition.

ii) Safflower oil content (%)

Oil content due to intercropping systems with different row proportion recorded non-significant difference between treatment combinations. Among all treatment combination, sole safflower recorded higher oil content (31 %) (Table: 5). However, it was found on par with 1:1 ratio of safflower + linseed (30 %) (Table: 5) and lowest oil content was recorded in 2:2 ratio of safflower + linseed (28 %) (Table: 5). This might be attributed to lower seed yield due to less plant population level of linseed. These results are in conformity with the finding of Aladkatti *et al*. (2010) and Prasad *et al.* (1993) [23]. The values reported in this study are below the 35–45% range, which is the average content range found in the literature (Kaya *et al*., 2003; Mahasi *et al*., 2009) [13, 19]. That is due to the genotype used in the study, which presents low oil content. Elfadl *et al*. (2009) [8] also observed that the obtained oil content in temperate conditions with nitrogen rates was low (22%), which, according to the authors, is due to the crop used in the study and the environment.

Table 5: Oil content and oil yield of safflower as influenced by varying row proportion in intercropping system of safflower and linseed

Treatment	Oil content (%)	Oil yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1 – Safflower + linseed (1:1) 30 cm rows	30	337	289	0.36
T_2 – Safflower + linseed (1:2) 30 cm rows	29	374	348	0.36
T_3 – Safflower + linseed (2:1) 30 cm rows	29	219	200	0.41
T_4 – Safflower + linseed (2:2) 30 cm rows	28	239	234	0.38
T_5– Mixed cropping of safflower and linseed (100:20)	30	390	125	0.33
T_6 – Sole safflower (60 cm x 30 cm)	31	434	-	-
T_7 – Sole linseed (30 cm x 5 cm)	-	-	1677	0.30
S.Em.±	0.53	6.16	14	0.01
C.D. (P=0.05)	NS	18.99	42	0.02

4. Conclusion

The increase in total dry matter production and oil yield was noticed in sole crop as compared to rest other treatments mainly because of in intercropping there is intense competition for moisture and nutrient uptake so there is plant growth is affected as a result photosynthesis rate is altered and reduced the yield. However, in sole crop there is no competition like as in intercropping system resulted more photosynthesis rate and seed yield.

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