Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(4): 176-179
Received: 25-05-2019
Accepted: 27-06-2019

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Comparative productivity and profitability of safflower (*Carthamus tinctorius* L.) based intercropping systems under protective irrigation on vertisol

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Abstract
An experiment was conducted at the Research Farm, Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during *rabi* seasons of 2016-17 and 2017-18. Sixteen intercropping treatments including sole crops were tested in randomized block design. Safflower crop and intercrops *viz.*, sorghum, wheat, chickpea, lentil and linseed were tested in 1:3 and 2:4 row proportions in replacement series. Safflower variety PBNS-12, sorghum variety Parbhani Moti, wheat variety Trimbak, chickpea variety Akash, lentil variety JL-3 and linseed variety PKVNL-260 were used. Pooled results revealed that safflower + chickpea (2:4) intercropping system recorded highest Safflower Equivalent Yield (2214 kg ha^{-1}) followed by sole chickpea (2144 kg ha^{-1}), sole safflower(2125 kg ha^{-1}) and safflower + chickpea (1:3) intercropping system (2099 kg ha^{-1}). Gross Monetary Returns, Net Monetary Returns and B: C ratio followed the similar trend. It can be concluded that safflower + chickpea (2:4) intercropping system is beneficial among all safflower based intercropping systems under protective irrigation on vertisol followed by sole chickpea, sole safflower and safflower + chickpea (1:3) intercropping system.

Keywords: Safflower, intercropping, safflower equivalent yield, protective irrigation vertisol

Introduction
Safflower (*Carthamus tinctorius* L.) is an important *Rabi* oilseed crop of Maharashtra. Apart from its superior adaptability to scanty moisture conditions, it produces oil rich in polyunsaturated fatty acids (Linoleic acid, 78%) which play an important role in reducing the blood cholesterol level. The safflower area in the country during 2017-18 was 0.81 lakh ha area as compared to the year 2016-17 (1.05 lakh ha).
The safflower was grown on 0.54 and 0.34 lakh ha area in Maharashtra during 2016-17 and 2017-18, respectively (Anonymous, 2018) [1]. The production of safflower in India was 0.94 and 0.54 million tonnes during 2016-17 and 2017-18 according to final and third advance estimates, respectively (Anonymous, 2018a) [2]. In India, Maharashtra and Karnataka are the two most important safflower growing states. The results of frontline demonstrations indicated that cultivation of safflower recorded the highest B: C ratio (4.60) and net returns (Rs. 19675 ha^{-1}) as compared to lower net returns (Rs. 13592 ha^{-1}) and B:C ratio (3:1) by Bengal gram. (Kumar *et al.* 2009) [4]. Intercropping is defined as any cropping system where there is a significant amount of inter-crop competition (Willey and Rao, 1980) [10].

Methodology
A field experiment was conducted on experimental farm of Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during the *rabi* seasons of 2016-17 and 2017-18. The soil of the experimental site was grouped as clayey in texture (54.30% clay), alkaline in nature (pH 7.84), low in available nitrogen (209.16 kg ha^{-1}), medium in available phosphorus (15.26 kg ha^{-1}), fairly rich in available potassium (501.60 kg ha^{-1}) and medium in organic carbon (0.56%). Sixteen intercropping treatments including sole crops were tested in randomized block design. Safflower crop and intercrops *viz.*, sorghum, wheat, chickpea, lentil and linseed were tested in 1:3 and 2:4 row proportions in replacement series. Safflower variety PBNS-12, sorghum variety Parbhani Moti, wheat variety Trimbak, chickpea variety Akash, lentil variety JL-3 and linseed variety PKVNL-260 were used.
The equation for calculating safflower equivalent yield (SEY) as suggested by Verma and Modgal (1983) [8] was used

$$SEY = \sum_{i=1}^{n} (Yi, ei)$$

Where,
SEY - safflower equivalent yield (kg ha-1)
Y - Economic yield of 1 to n number of crops
e - Safflower equivalent factor which can be calculated as

$$\frac{PC}{PS}$$

Where,
PC – Price of unit weight of concerned crop
PS – Price of unit weight of safflower
i – 1 to n number of crops.

For economic evaluation of intercropping systems, gross monetary returns, net monetary returns, cost of cultivation and benefit: cost ratio were computed treatment wise on crop and system basis and expressed as $Rs.ha^{-1}$

Results and Discussion

Perusal of data presented in Tables 1 (Figure 1) revealed that the total productivity of the safflower based intercropping systems expressed in terms of safflower equivalent yield indicated that it differed significantly due to intercropping treatments in both the crops during both the years of investigation and in pooled results also. During first year of study, significantly higher safflower equivalent yield was recorded by sole chickpea; however, it was on par with safflower + chickpea (2:4) and safflower + chickpea (1:3) intercropping systems, respectively. Sole lentil produced significantly lowest safflower equivalent yield among all treatments. During second year of investigation, sole safflower registered significantly higher safflower equivalent yield which was on par with safflower + chickpea (2:4) intercropping system. Sole lentil produced significantly lowest safflower equivalent yield among all treatments. Pooled results of two years, revealed that safflower + chickpea (2:4) intercropping system produced significantly higher safflower equivalent yield of safflower based intercropping systems, however, it was on par with sole chickpea, sole safflower and safflower + chickpea (1:3) intercropping system. Sole lentil recorded significantly lowest safflower equivalent yield. Willey and Rao (1981) [10] in his experiment on intercropping reported that an initial increase in safflower population caused an increase in chickpea yield at the 1:1 arrangements, otherwise increasing safflower population decreased chickpea yields. Safflower was usually a dominant species and increasing the total population (i.e. both crops combined) made it more so, safflower yield was little affected by changes in its own population and was independent of changes in chickpea populations. Intercropping of chickpea and safflower was more remunerative than a pure crop of either chickpea or safflower. These findings are in consonance with those reported by Rao *et al*. (1997) [6], Pawar and Karle (1999) [5], Anonymous (2006) [3] and Wasu (2011) [9].

The gross monetary returns, net monetary returns and benefit cost ratio of safflower based intercropping systems were significantly influenced by intercropping treatments during both the seasons and on pooled mean basis (Table 2; Figure 2&3). During 2016-17 and 2017-18, significantly higher mean gross and net monetary returns were recorded by sole chickpea and sole safflower, respectively, however, these crops were on par with safflower + chickpea (2:4) and safflower + chickpea (1:3) intercropping systems. Pooled results of two years, revealed that safflower + chickpea (2:4) intercropping system recorded significantly higher mean gross and net monetary returns, however, it was on par with sole chickpea, sole safflower and safflower + chickpea (1:3) intercropping system. Sole lentil and sole wheat recorded significantly lower mean gross and net monetary returns during first and second year of experimentation, respectively. Different types of demonstrations conducted across the states over years revealed that different safflower based intercropping systems have proved to be economically viable as reflected by the increased productivity, additional net returns and higher B:C ratio (Anonymous, 2006) [3]. Willey and Rao (1981) [10] also mentioned that intercropping of chickpea and safflower was more remunerative than a pure crop of either chickpea or safflower. Sarkar *et al*. (2000) [7] also reported that intercropping of chickpea and safflower recorded higher gross and net returns and B: C ratio as compared to other intercropping systems and sole stands.Significantly superior mean benefit: cost ratio was recorded by safflower + chickpea (2:4) intercropping system during 2016-17 over rest of the treatments, however, it was on par with sole chickpea and safflower + chickpea (1:3) intercropping systems in recording mean benefit: cost ratio. During 2017-18, sole safflower recorded significantly highest mean benefit: cost ratio. Pooled data of two years revealed that sole safflower recorded significantly higher mean benefit: cost ratio of safflower based intercropping systems, however, it was on par with safflower + chickpea (2:4) intercropping system. Sole wheat recorded significantly lower mean benefit: cost ratio, however, it was on par with safflower + wheat intercropping system and sole lentil. Kumar *et al.* (2009) [4] also reported that cultivation of safflower recorded the highest monetary returns and B: C ratio compared to Bengal gram and the lowest net returns and B: C ratio was recorded by wheat, whereas, intercropping of chickpea + safflower in 4:2 ratio recorded higher net returns and B:C ratio.The similar findings were reported by Anonymous (2006) [3] and Wasu (2011) [9]

Conclusion

On the basis of pooled results it can be concluded that safflower + chickpea (2:4 or 1:3) intercropping systems are beneficial for maximum productivity and increased profit under protective irrigation on vertisol.

Table 1: Mean safflower equivalent yield (SEY) (kg ha^{-1}) of safflower based intercropping system as influenced by different treatments (2016-17, 2017-18 and pooled)

Treatments	2016-17	2017-18	Pooled
Safflower + Sorghum (1:3)	1612	1640	1625
Safflower + Sorghum (2:4)	1703	1710	1705
Safflower + Wheat (1:3)	1376	1204	1288
Safflower + Wheat (2:4)	1797	1587	1690
Safflower + Chickpea (1:3)	2495	1709	2099
Safflower + Chickpea (2:4)	2590	1844	2214
Safflower + Lentil(1:3)	1398	1352	1370
Safflower + Lentil (2:4)	1583	1521	1548
Safflower + Linseed (1:3)	1569	1378	1468
Safflower + Linseed (2:4)	1710	1513	1606
Sole Safflower	2220	2030	2125
Sole Sorghum	1678	1691	1682
Sole Wheat	1344	1202	1271
Sole Chickpea	2691	1604	2144
Sole Lentil	1065	1070	1063
Sole Linseed	1360	1156	1364
SEm ±	96	82	63
C.D. =P(0.05)	278	237	177
G. mean	1762	1513	1638

Table 2: Mean gross monetary returns (Rs.ha^{-1}), mean net monetary returns (Rs.ha^{-1}) and mean benefit: cost ratio of safflower based intercropping system as influenced by different treatments (2016-17, 2017-18 and pooled)

Treatments	Mean gross monetary returns (Rs.ha^{-1})			Mean net monetary returns (Rs.ha^{-1})			Mean benefit: cost ratio		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Safflower + Sorghum (1:3)	53354	56571	54962	29090	32307	30698	2.20	2.33	2.27
Safflower +Sorghum (2:4)	56353	58986	57670	32249	34882	33566	2.34	2.45	2.39
Safflower +Wheat (1:3)	45532	41518	43525	19499	15485	17492	1.75	1.59	1.67
Safflower + Wheat (2:4)	59468	54741	57105	34015	29288	31652	2.34	2.15	2.24
Safflower +Chickpea (1:3)	82580	58949	70765	56791	33160	44976	3.20	2.29	2.74
Safflower + Chickpea (2:4)	85716	63615	74666	60257	38156	49207	3.37	2.50	2.93
Safflower +Lentil(1:3)	46288	46614	46451	24339	24665	24502	2.11	2.12	2.12
Safflower +Lentil (2:4)	52397	52471	52434	30351	30425	30388	2.38	2.38	2.38
Safflower + Linseed(1:3)	51943	47512	49728	31281	26850	29066	2.51	2.30	2.41
Safflower +Linseed (2:4)	56603	52169	54386	35701	31267	33484	2.71	2.50	2.60
Sole Safflower	73494	70011	71753	50650	47167	48909	3.22	3.06	3.14
Sole Sorghum	55547	58312	56929	30810	33575	32192	2.25	2.36	2.30
Sole Wheat	44483	41452	42968	15841	12810	14326	1.55	1.45	1.50
Sole Chickpea	89086	55317	72201	62315	28546	45430	3.33	2.07	2.70
Sole Lentil	35252	36891	36072	13602	15241	14422	1.63	1.70	1.67
Sole Linseed	45027	39875	42451	25093	19941	22517	2.26	2.00	2.13
SEm ±	3187	2831	2131	3187	2831	2132	0.13	0.12	0.09
C.D. =P(0.05)	9195	8169	5969	9195	8169	5969	0.37	0.35	0.25
G. mean	58320	52188	55254	34493	28360	31426	2.45	2.20	2.32

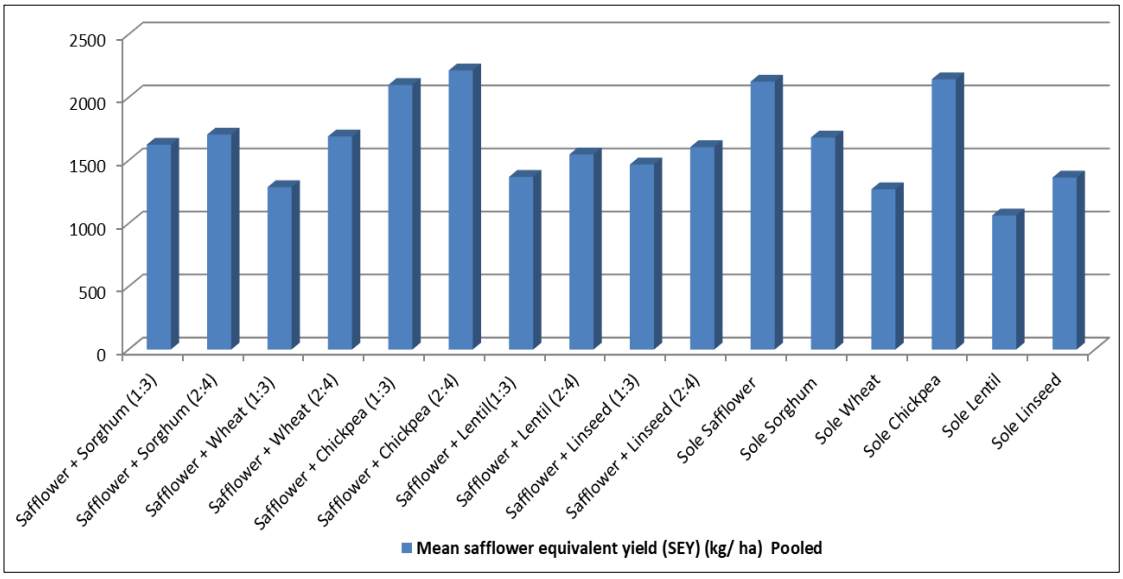

Fig 1: Mean safflower equivalent yield (SEY) (kg ha^{-1}) of safflower based intercropping systems as influenced by different treatments (pooled)

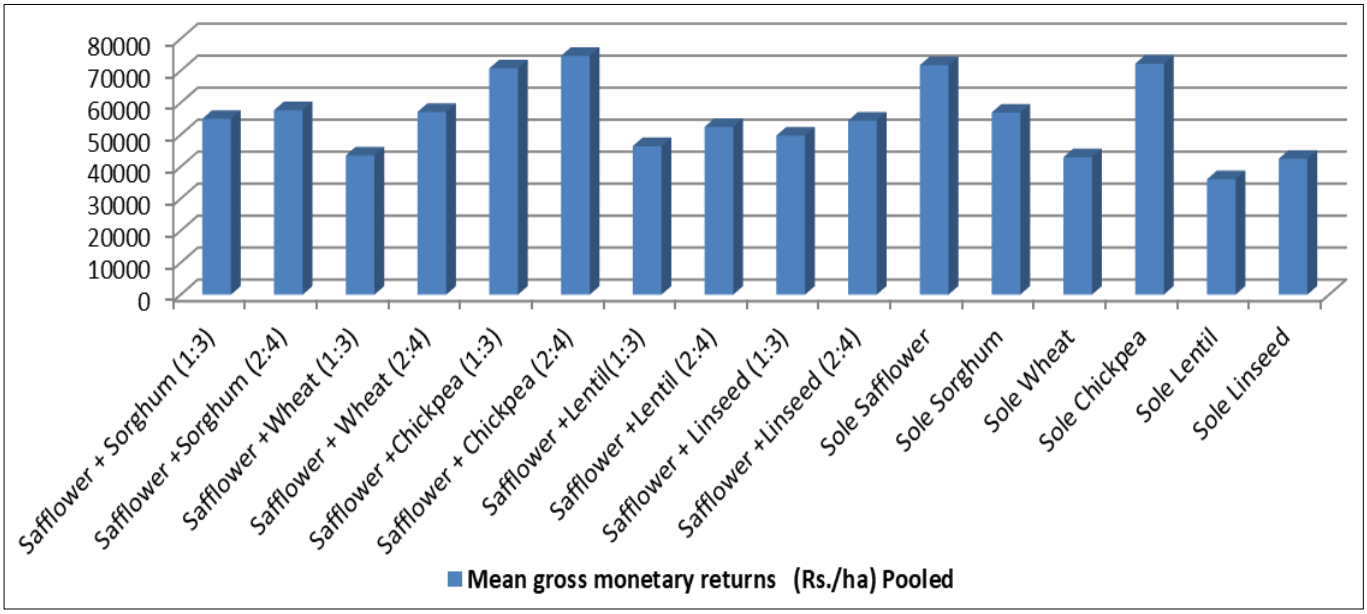

Fig 2: Mean gross monetary returns (Rs.ha^{-1}) of safflower based intercropping systems as influenced by different treatments (pooled)

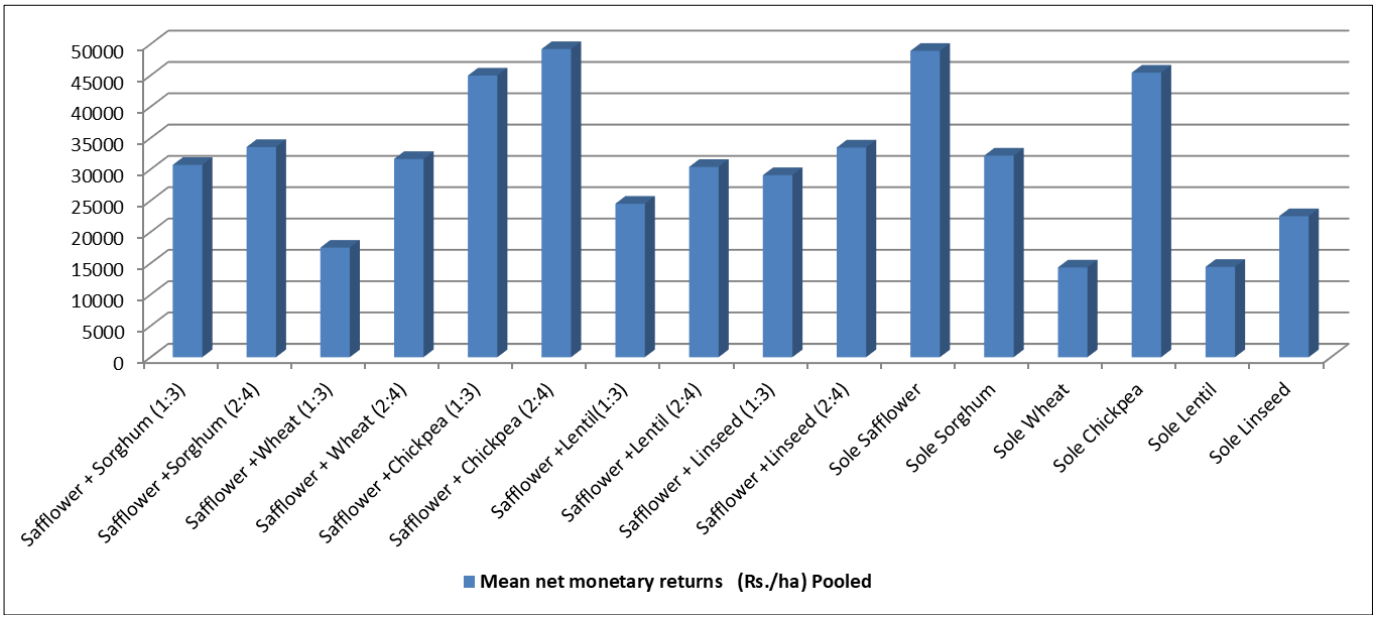

Fig 3: Mean net monetary returns (Rs.ha^{-1}) of safflower based intercropping systems as influenced by different treatments (pooled)

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