Performance of five Mexican safflower (*Carthamus tinctorius* L.) varieties/breeding lines under Indian conditions

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ABSTRACT

Safflower (*Carthamus tinctorius* L.), a drought tolerant crop, is capable of extracting moisture from deeper layers of soil. In India, more than 80 per cent of safflower is cultivated in Vertisols of Peninsular region during post-rainy season under residual soil moisture conditions. Five Mexican varieties/breeding lines (Ciano-Lin, CCC-B4, RC-1033-L, CCC-B2 and CW-99) were evaluated in 2014-15 under irrigated conditions along with two Indian varieties (NARI-57 and PBNS-12). Significant variation was found between Mexican varieties/breeding lines and Indian varieties with respect to plant height, days to first flowering, number of capitula/plant, seed yield, biological yield, oil content and oil yield. Seed and oil yield of CCC-B2 (2259; 800 kg/ha) was on par with that of NARI-57 (2298; 719 kg/ha). The Ciano-Lin recorded significantly low seed (1266 kg/ha) and oil yield (399 kg/ha).

Keywords: Indian varieties, Mexican varieties and breeding lines, Safflower, Yield potential

Safflower (*Carthamus tinctorius* L.) is a drought tolerant crop. It has a strong tap root system which draws moisture from fairly deeper layers of the soil profile (Hussain *et al.,* 2016). In the world, India occupies second place in area after Kazakhstan and third place in production after Kazakhstan and Mexico. In India, it is being cultivated in an area of 2.11 lakh ha with a production of 1.13 lakh tons (FAO STAT, 2017) with productivity of 536 kg/ha. Average productivity of safflower in Mexico is 1260 kg/ha which has enabled Mexico to occupy the second position in production even though less area is under cultivation compared to India.

In India, safflower is basically grown in post-rainy season in Vertisols under receding soil moisture conditions. It is cultivated mainly in Maharashtra (58%), Karnataka (21%), Gujarat (12%) and to a limited extent in Telangana, Madhya Pradesh, Chhattisgarh, Odisha and Bihar (IIOR, 2016; Padmavathi *et al.,* 2017). Productivity is quite low (536 kg/ha) as the crop is being grown by resource poor farmers with poor crop management practices under biotic and abiotic stress conditions.

Safflower is thermo-sensitive crop, which needs cool temperatures (15-20°C) for root growth and rosette development and moderate temperatures of 20-32°C during crop growth, flowering and capitula formation (Shabana *et al.,* 2013). One of the drawbacks associated with safflower cultivation is very thick hull of the native varieties which adversely limits the per hectare yield of oil as well as the quantity and quality of the meal, thereby, making its cultivation less attractive. Apart from their low yield potential, all the available exotic germplasm resources with high oil content show poor adaptability to Indian conditions. Considering the importance of increasing safflower production, efforts are needed to breed cultivars with high oil yield coupled with abiotic stress tolerance there by increasing the profitability of safflower cultivation. The incorporation of alleles for low hull and/or high oil content into the genetic background of locally adapted agronomic base should form an important breeding activity in the immediate future (Kadirvel *et al.,* 2016; Kadirvel *et al.,* 2017). This study was undertaken to quantify the productivity potential, in terms of seed and oil yield, of a few Mexican varieties /breeding lines in comparison to Indian varieties.

A set of five promising varieties/breeding lines of safflower, *viz,* Ciano-Lin (EC 755688), CCC-B4 (EC 755671), RC-1033-L (EC 755687), CCC-B2 (EC 755669) and CW-99 (EC 755664), with higher seed yield potential were selected from among the lines obtained from Instituto Nacional de Investigaciones Forestales, Agricolasy Pecuarias (INIFAP), Campo Experimental Valle del Yaqui, Sonora, Mexico. These five lines along with two Indian cultivars *viz*., NARI-57 and PBNS-12 were evaluated under irrigated conditions in 2014-15. Field experiment was carried out at ICAR-Indian Institute of Oilseeds Research farm located at ICRISAT (between 17°25" latitude and 78° longitude at 545 m above sea level) during the *rabi* season of 2014-15 in deep Vertisols under irrigated conditions. Only one irrigation was given immediately after sowing. The soil was low in available nitrogen (204 kg/ha), low in P (8.1 kg/ha) and high in K (837 kg/ha). Bulk density of top 0-15 cm soil was 1.6 g/cm^3. Soil moisture content at field capacity and permanent wilting point in the upper 0-30 cm surface was 0.45 and 0.30 g/g soil respectively.

The experiment was laid out in randomized block design (RBD) with three replications. Crop was sown on ridges in the last week of October with 45 cm spacing. Thinning was done at 25 days after sowing to maintain one plant/hill of 20

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cm distance within a row. Recommended agronomic practices were followed. Entire recommended fertilizer dose (40:25:0 N:P_2O_5:K_2O kg/ha) was applied at the time of sowing. Nitrogen and phosphorus were applied in the form of urea and single super phosphate respectively and incorporated into the seedbed before sowing. Weeds were controlled mechanically and by hand-hoeing at 30 and 60 days after sowing. Aphids were controlled with chlorpyriphos 20 EC (2.5 ml/l). Safflower plants were manually harvested at physiological maturity. At maturity, data on plant height, number of capitula, weight of capitula, seed weight and 100-seed weight on main stem, primary, secondary and tertiary branches were taken in five randomly selected plants in the row next to border rows on either side of each plot without disturbing the net plot. Oil content was measured by Nuclear Magnetic Resonance (NMR) spectroscopy using 30 g of seed sample from each plot. Crop growth and yield data was analyzed using SAS9.3 (SAS Institute, Cary NC).

Growing environment of India vs Mexico: In India safflower crop matures in 120 days whereas in Mexico the crop takes 150 days to mature. In India, the crop is sown in September/October and harvested by January/February whereas in Mexico, it is sown in December/January and harvested by May/June (Padmavathi and Virmani, 2013). Mean minimum temperature during vegetative stage was 20.2°C in India and 8.6°C in Mexico. Mexican varieties/breeding lines showed lesser crop duration (~120 days) due to lesser rosette period because of warm conditions (compared to Mexican conditions) during vegetative stage of crop growth.

Soil profile (2 m) was brought into saturated condition (200 mm) with one irrigation immediately after sowing. Mean temperatures during crop growth were similar to normal temperatures and soil moisture was not a limiting factor (Table 1). Mexican varieties/breeding lines recorded seed yield of 1644 kg/ha and Indian cultivars recorded 2249 kg/ha.

Morphology and phenology: Mexican varieties /breeding lines did not differ significantly in their morphology in terms of plant height, total dry matter (g/plant) at harvest though the cultivars differed in days to first flower character (Table 2). The days to first flower variation ranged from 76 to 86 days after sowing (DAS) among the cultivars tested and 81 to 86 DAS among the Mexican varieties/breeding lines with Ciano-Lin flowering late (86 DAS), whereas Indian varieties flowered early by 7 to 10 days. Among the Mexican varieties/breeding lines, CCC-B2 flowered in 81 days which was the earliest and statistically on par with that of Indian cultivar NARI-57.

Table 1 Monthly rainfall (mm) and monthly mean of temperature (°C) and relative humidity (%) in 2014-15 during cropping period

Month	Rainfall (mm)		Mean Temperature (°C)		Relative Humidity (%)	
	2014-15	Normal*	2014-15	Normal*	2014-15	Normal*
June	42.2	116.6	30.7	29.0	58.7	63.1
July	60.3	183.4	27.4	26.6	72.4	74.3
August	101.8	222.8	27.1	25.6	75.2	78.9
September	47.6	159.3	26.0	25.9	78.3	77.7
October	47.4	98.9	25.6	25.0	68.9	71.2
November	55.8	21.3	22.8	22.5	66.5	66.7
December	0	3.1	20.4	20.5	64.7	63.6
January	4.6	7.9	20.4	21.2	62.6	62.5
February	0	6.4	23.3	23.9	54.4	54.4
Total/Mean	360	820	24.9	24.5	66.9	68.0

*Normal refers to the long-term average (44 years average)

Yield and its components: The seed yield and its components *viz.,* number of primary, secondary, tertiary and total capitula per plant varied among Mexican varieties/breeding lines and were less compared to Indian varieties. The range of variation was from 14 to 22 in primary capitula, 27 to 36 in secondary, 12 to 25 in tertiary capitula and 59 to 82 in total number of capitula/plant. Among all, Indian cultivars showed good number of secondary, tertiary capitula and total number of capitula/plant, that might have led to better seed yield in comparison to Mexican varieties/breeding lines except CCC-B2. Though the number of secondary, tertiary and total capitula/plant were less in CCC-B2 (27; 23 and 70) compared to Indian varieties NARI-57 (34; 25; 79) and PBNS-12 (36; 24; 82), the seed yield was on par with Indian varieties. This could be due to higher seed weight/capitula/plant in main stem, primary, secondary, tertiary and total seed weight in CCC-B2 (1.3; 24.8; 26.4;

9.1; 61.6 g) compared to Indian varieties NARI-57 (0.8; 20.8; 24; 8.1; 53.7 g) and PBNS-12 (1.2; 22.8; 25.7; 8.5; 58.2 g). Seed yield is known to be significantly associated with the number of capitula per plant and seed weight/capitula (Amir Hassan *et al*., 2012). Seed yield of NARI-57 was maximum (2298 kg/ha) while that of Mexican variety Ciano-Lin was minimum (1266 kg/ha) (Table 2). Yield components *viz.,* seed weight per capitula, 100 seed weight (Table 2) indicated that the seed per main stem, secondary, tertiary capitulum had better filling in CCC-B2, NARI-57 and PBNS-12, respectively compared to other Mexican lines. The 100 seed weight was maximum in CCC-B2, RC1033-L, CCC-B4 at 5.5, 4.8, 4.5 g/plant and minimum was in Ciano-Lin (3.1 g/plant).

Harvest index, oil content and oil yield: The harvest index (HI) varied from 15 to 27% among the Mexican and Indian varieties (Table 1). Genotypes CCC-B2 (from Mexico), NARI-57 and PBNS-12 (India) recorded HI of 31, 29 and 27% respectively. Higher yield with higher HI indicates better partitioning of photosynthetic substance to economic yield which can be considered as a good trait in any cultivar. Among other Mexican varieties/breeding lines, Ciano-Lin and RC-1033-L recorded significantly higher biological yield and lower HI. These results clearly indicated the poor partitioning efficiency in these two varieties/breeding lines with high biomass as compared to CCC-B2 and NARI-57.

The range of oil content varied from 23 to 35% among the cultivars tested. The CCC-B2 had maximum oil content 35.4% and PBNS-12 recorded minimum oil content 23.1%. Oil yield was significantly higher in CCC-B2 (800 kg/ha) and NARI-57 (719 kg/ha) as compared to the other four Mexican varieties/breeding lines (399; 498; 516 and 602 kg/ha) and Indian variety PBNS-12 (508 kg/ha). However oil yield was less (399 kg/ha) in Ciano-Lin though its oil content was reasonably good (31.5 %) due to lowere seed yield (1266 kg/ha) among seven entries tested.

This study established that Mexican genotype CCC-B2 was statistically on par with that of Indian cultivar NARI-57 in terms of seed and oil yield productivity.

Table 2 Productivity of Mexican varieties/breeding lines and Indian varieties of safflower

Treatment	Plant height (cm)	Days to first flower	Drymatter at harvest (g/plant)	No. of capitula/plant				Seed yield (kg/ha)	Biological yield (kg/ha)	H.I (%)	Oil content (%)	Oil yield (kg/ha)
				Primary	Secondary	Tertiary	Total					
Ciano-Lin	118	86	187	20	27	21	69	1266	8683	15	31.5	399
CCC-B4	114	85	170	14	29	21	65	1427	7078	20	34.9	498
RC-1033-L	116	85	187	19	27	12	59	1762	8354	21	34.2	602
CCC-B2	117	81	181	19	27	23	70	2259	7202	31	35.4	800
CW-99	115	84	182	18	28	20	67	1504	7325	21	34.3	516
NARI-57	112	80	176	19	34	25	79	2298	7860	29	31.3	719
PBNS-12	110	76	180	22	36	24	82	2200	8150	27	23.1	508
S.Em±	1.3	0.7	7.7	2.9	2.3	2.3	3.3	89.6	285		0.8	41.3
C.D ($p \leq 0.05$)	3.6	2	NS	NS	NS	7	10	258	820		2.4	124

Table 3 Growth and yield attributes of Mexican varieties/breeding lines and Indian varieties of safflower

Treatment	Capitula weight (g/plant)					Seed weight (g/capitula order/plant)					100-seed weight (g)				
	Main stem	Primary	Secondary	Tertiary	Total	Main stem	Primary	Secondary	Tertiary	Total	Main stem	Primary	Secondary	Tertiary	Mean
Ciano-Lin	3.5	41.3	43.3	28.4	116.5	1.1	17.9	18.7	7.0	44.7	3.1	3.6	2.9	2.6	3.1
CCC-B4	2.0	26.3	44.2	21.9	94.4	1.0	13.9	16.4	8.8	40.1	3.4	4.9	5.1	4.4	4.5
RC-1033-L	2.6	47.2	46.2	23.5	119.5	1.3	19.4	18.5	6.2	45.4	4.3	5.1	4.2	5.5	4.8
CCC-B2	2.4	39.2	44.4	27.6	113.6	1.3	24.8	26.4	9.1	61.6	4.9	5.6	5.3	6.2	5.5
CW-99	4.3	33.7	46	24.8	108.8	1.0	15.6	19.3	7.3	43.2	3.6	4.1	4.1	3.7	3.9
NARI-57	1.5	32.1	42.5	24.5	100.6	0.8	20.8	24.0	8.1	53.7	3.5	4.4	4.1	3.5	3.9
PBNS-12	1.8	30.8	46.5	26.5	105.6	1.2	22.8	25.7	8.5	58.2	4.8	4.6	3.8	3.5	4.2
S.Em±	1.2	5.9	4.1	3.0	8.4	0.13	2.7	2.2	1.5	3.5	0.45	0.5	0.6	0.56	0.42
C.D ($p \leq 0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.6	1.2

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