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Research Communication

Performance of canola oilseed rape (*Brassica napus*), Ethiopian mustard (*Brassica carinata*) and Indian rape (*Brassica rapa*) in the intercropping system

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ABSTRACT

A field experiment was conducted at Ludhiana, Punjab, during the winter (*rabi*) season of 2014–15, to study the production potential of Indian rape (*Brassica rapa var. toria)*, oilseed rape (*Brassica napus* L.) and Ethiopian mustard (*Brassica carinata* A. Braun) in different row spacings and row proportions in the intercropping systems. The experiment comprised 14 treatments which were replicated thrice as per randomized complete-block design. Plant height at maturity and dry-matter accumulation (DMA) at 90 days after sowing by component crops decreased significantly in intercropping as compared to their sole crops and such reduction in plant height was more for the narrow row spacing, and for DMA with increasing row spacing. Number of siliquae/plant and 1,000- seed weight of Indian rape and Ethiopian mustard, and number of seeds/siliqua of Ethiopian mustard were not influenced by the intercropping. The highest seed yield given by Indian rape (1.16 t/ha) in Ethiopian mustard + Indian rape intercropping system (1:2, 22.5 cm) was 80.5% of its sole crop yield. Seed yield of non-canola oilseed rape when intercropped with Indian rape (1:1, 22.5 cm) was 45.7% lower than its sole crop yield (1.85 t/ha). However, oilseed rape-equivalent yield produced by non-canola oilseed rape + Indian rape (1 : 1, 22.5 cm) was 22.9% higher than sole non canola oilseed rape. Similarly, sole crop of canola oilseed rape (1.63 t/ha) gave 91.0, 60.2 and 35.3% higher seed yield than its yield under intercropping with Indian rape in different row proportions and spacing. Oilseed rape- equivalent yield in the canola oilseed rape + Indian rape sown in 1 : 1 and 2 : 1 row proportion at 22.5 cm row spacing was 16.9 and 20.1% higher than sole canola oilseed rape (1.63 t/ha). Similar to seed yields, stover yields of component crops were significantly decreased in the intercropping system (ICS). Canola/ non-canola oilseed rape based intercropping system (ICS) resulted in higher net returns than sole crops, whereas Ethiopian mustard sown as sole crop was more remunerative than its intercropping with Indian rape.

Key words : *Brassica* species, Growth, Income, Intercropping, Oil content, Yield, Yield attributes

Despite largest area under oilseeds (28.53 million ha) in the world, annual vegetable oils production (9.86 million tonnes) is less than 50% of the domestic requirements in India. Thus has compelled the country to import about 11.55 million tonnes of edible oil worth ₹59,094 crore (DAC, 2015–16). The situation demands concerted efforts to increase production and productivity of oilseeds in the country to bridge the demand-supply gap and reduce outflow of massive foreign exchange. With limited scope of horizontal expansion (increase in area) of oilseeds, vertical expansion (intercropping) of these crops has been emphasized to increase land productivity/unit area and time, for enhancing production of vegetable oil in the country. Rapeseed–mustard group of oilseed crops, namely, Indian mustard, oilseed rape, Indian rape, taramira are often intercropped with wheat, chickpea, lentil, sugarcane, potato etc. under different agro-climatic zones of India (Srivastava *et al.,* 2008).

Canola (double zero) cultivars of rapeseed–mustard which are almost free from erucic acid (< 2%) and possess higher oleic acid (> 60%) content in oil and lower concentration of glucosinolates in seed meal (< 30 µmoles/g defatted seed meal) are nutritionally superior to conventional non-canola cultivars. Due to longer duration, slow initial growth and late flowering, non-canola oilseed rape can be successfully intercropped with short-duration Indian rape (Sardana and Sidhu, 1994). Ethiopian mustard owing to its tolerance to abiotic stresses, resistance to white rust and

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higher yield potential is gaining importance in several parts of the world as a potential crop for use as biofuel (Taylor *et al.,* 2010). The present investigation was carried out to study the compatibility of nutritionally superior canola oilseed rape and recently synthesized seed-shattering resistant, dwarf and determinate Ethiopian mustard in the intercropping system (ICS) with Indian rape.

The field experiment was conducted at the research farm of the Punjab Agricultural University, Ludhiana, during the winter (*rabi*) season of 2014–15 on loamy sand soil. The soil of experimental field in the 0–15 soil layer was free from salts (electrical conductivity 0.12 dS/m), neutral in reaction (*p*H 7.2), low in organic carbon content (0.28%) and potassium permanganate available nitrogen (188 kg/ha), rich in Olsen's available phosphorus (28 kg/ha) and medium in NH_4OAc-extractable available potassium (148 kg/ha). The study was conducted in randomized complete-block design with 14 treatments (Tables 1 and 2) in 3 replications. Test cultivars 'TL 17' of Indian rape, 'GSC 7' of canola oilseed rape, 'GSL 1' of non-canola oilseed rape and 'BJC 13–4' of Ethiopian mustard were sown as per treatments on 18 September 2014. Plant-to-plant spacing of 10 cm within row was maintained 3 weeks after sowing. Application of 62.5 kg N and 20 kg P_2O_5/ha to sole crop of Indian rape was made at sowing. Nitrogen @ 100 kg/ha was applied to both oilseed rape and Ethiopian mustard. Basal application of 30 kg P_2O_5/ha and 15 kg K_2O/ha along with 50% of N (on area basis in case of intercropping treatments) was made at time of field preparation before last planking. The remaining dose of N to oilseed rape and Ethiopian mustard was applied after harvesting of Indian rape. Gross plot size was 18.0 m^2 (3.6 m × 5.0 m). Indian rape was harvested 94 days after sowing, while Ethiopian mustard and oilseed rape were harvested at 164 days after sowing.

Intercropping of Indian rape with canola oilseed rape (1 : 1) at 22.5 cm row spacing resulted in significantly lowest plant height of Indian rape (Table 1). The dry-matter accumulation (DMA) by component crops decreased with the increasing row spacing and decreasing row proportion in the intercropping system (ICS). The DMA by sole crops at maturity stage of Indian rape was significantly higher (except in non-canola oilseed rape) than their respective DM in the ICS 1). Intercropping of canola oilseed rape with Indian rape (1 : 1, 22.5 cm apart rows) resulted in total DMA (7.0 t/ha) at par with Ethiopian mustard + Indian rape (1 : 2, 22.5 cm; 2 : 1, 22.5; 1 : 1, 22.5 cm and 1 : 1, 30.0 cm apart rows) and canola oilseed rape + Indian rape (2:1, 22.5 cm apart rows).

Sole crop of canola oilseed rape produced significantly more number of siliquae/plant than canola or non-canola oilseed rape in intercropping system. Ethiopian mustard showed higher siliquae-bearing capacity owing to its higher number of primary and secondary branches/plant than Indian rape and oilseed rape. Sole crop of Indian rape and non-canola oilseed rape produced significantly more seeds/siliqua than their intercropping (Table 1). Thousand seed weight of Indian rape and Ethiopian mustard in intercropping system was at par with their respective sole crops, whereas canola oilseed rape as sole crop or intercropped with Indian rape (2 : 1, 22.5 or 30.0 cm row spacing) produced significantly higher 1,000-seed weight than canola oilseed rape + Indian rape (1 : 1, 22.5 cm row spacing (Table 1).

Seed yield of Indian rape (1.16 t/ha) in Ethiopian mustard + Indian rape (1 : 2) at 22.5 cm apart rows was 10.2% and 15.5% higher than Ethiopian mustard + Indian rape (1:1) sown at 22.5 cm and 30 cm row spacing, respectively, and 67.6% and 79.5% higher than Ethiopian mustard + Indian rape (2 : 1) at 22.5 cm and 30 cm row spacing, but 24.2% lower than sole crop of Indian rape (Table 2). Similarly seed yield of Indian rape from canola oilseed rape + Indian rape (1 : 1) at 22.5 cm apart rows (1.08 t/ha) was 11.9% and 75.1% higher than its yield in canola oilseed rape + Indian rape (2 : 1) at 22.5 cm, and 30 cm row spacing, but 33.6% lower than sole crop of Indian rape (1.44 t/ha). Apart from competition from oilseed rape and Ethiopian mustard, plant population of Indian rape in intercropping system also varied according to row ratios. These differences in plant population caused differences in seed yield.

Sole crop of non-canola oilseed rape significantly outyielded the sole crop of canola oilseed rape by margin of 13.4%, whereas its yield in the intercropping system decreased by 45.7% (Table 2). Seed yield of sole crop of canola oilseed rape was 91.0, 60.2 and 35.3% higher than its intercropping with Indian rape at 22.5 cm row spacing in 1 : 1 and 2 : 1 row proportions and 30 cm row spacing in 2:1 row proportion, respectively. Both canola and non-canola oilseed rape differed in their growth pattern and non-canola oilseed rape with slow initial growth was more compatible for intercropping with Indian rape. Gupta and Saini (1986) reported similar results for non-canola oilseed rape + Indian rape intercropping system.

Ethiopian mustard sown at 30 cm (2.25 t/ha) or 45 cm (2.15 t/ha) row spacing gave significantly higher seed yield (41.5%–128.8%) than under different intercropping systems (Table 2). The highest seed yield of Ethiopian mustard obtained from Ethiopian mustard + Indian rape in 2 : 1 row proportion at 30 cm row spacing (1.59 t/ha) was 18.5, 45.3, 32.6 and 61.7% higher than its yield from 2 : 1 at 22.5 cm; 1 : 1 at 22.5 and 1 : 1 at 30 cm and 1 : 2 row proportion at 22.5 cm row spacing, respectively. Higher seed yield of Ethiopian mustard under 30 row spacing was

Table 1. Growth and yield attributes of component crops in Indian rape, oilseed rape and Ethiopian mustard intercropping systems

Treatment	Plant height (cm)			Dry-matter accumulation (t/ha) at 90 DAS				Siliquae/plant			Seeds/siliqua			1,000-seed weight (g)		
	*IR	*OR	*EM	IR	OR	EM	Total	IR	OR	EM	IR	OR	EM	IR	OR	EM
Canola oilseed rape + Indian rape at 22.5 cm (1:1)	116.4	179.7	-	5.12	1.88	-	7.00	267.9	356.5	-	18.0	17.5	-	3.2	4.3	-
Canola oilseed rape + Indian rape at 22.5 cm (2:1)	126.1	192.7	-	4.15	2.55	-	6.70	283.3	352.7	-	19.9	17.5	-	3.0	5.0	-
Canola oilseed rape + Indian rape at 30 cm (2:1)	121.2	188.3	-	3.20	1.99	-	5.19	287.2	347.4	-	17.1	17.4	-	3.2	5.1	-
Ethiopian mustard + Indian rape at 22.5 cm (1:1)	122.4	-	185.7	4.65	-	1.48	6.13	268.9	-	427.9	17.0	-	13.5	3.0	-	4.3
Ethiopian mustard + Indian rape at 30 cm (1:1)	124.1	-	194.7	4.86	-	1.59	6.45	294.9	-	463.3	18.5	-	13.6	3.0	-	4.6
Ethiopian mustard + Indian rape at 22.5 cm (2:1)	121.9	-	192.7	3.95	-	2.77	6.72	270.9	-	459.7	17.8	-	14.2	3.1	-	4.7
Ethiopian mustard + Indian rape at 30 cm (2:1)	126.6	-	190.3	2.51	-	2.30	4.81	288.9	-	479.5	17.1	-	14.0	3.3	-	4.6
Ethiopian mustard + Indian rape at 22.5 cm (1:2)	125.4	-	194.0	5.44	-	1.40	6.84	245.9	-	416.2	18.4	-	13.8	3.2	-	4.4
Non-canola oilseed rape + Indian rape at 22.5 cm (1:1)	124.1	179.0	-	4.26	1.74	-	6.00	244.7	320.1	-	18.1	18.1	-	3.4	3.3	-
Canola oilseed rape at 45 cm	-	202.3	-	-	2.20	-	2.20	-	492.8	-	-	18.1	-	-	5.0	-
Ethiopian mustard at 30 cm	-	-	194.0	-	-	5.95	5.95	-	-	489.6	-	-	13.1	-	-	4.6
Ethiopian mustard at 45 cm	-	-	194.3	-	-	3.80	3.80	-	-	528.7	-	-	13.5	-	-	4.6
Non-canola oilseed rape at 45 cm	-	198.7	-	-	2.51	-	2.51	-	427.1	-	-	19.1	-	-	3.5	-
Indian rape at 30 cm	131.0	-	-	6.24	-	-	6.24	311.8	-	-	21.7	-	-	3.5	-	-
SEm±	1.9	3.2	3.2	0.39	0.31	0.37	0.45	28.3	36.0	46.0	1.2	0.3	0.7	0.1	0.3	0.2
CD (P=0.05)	4.0	7.2	NS	0.82	NS	0.80	0.93	NS	80.3	NS	2.5	0.6	NS	NS	0.6	NS

*IR, Indian rape; OR, oilseed rape; EM, Ethiopian mustard

owing to its more plant population compared to 45 row spacing.

Intercropping of non-canola oilseed rape with Indian rape (1 : 1) at 22.5 cm row spacing resulted in the highest oilseed rape-seed equivalent yield (2.27 t/ha) which was 22.9% (significantly) higher than sole crop of non canola oilseed rape (1.85 t/ha). In case of canola oilseed rape, equivalent seed yield of canola oilseed rape + Indian rape sown at 22.5 cm row spacing in 1 : 1 (1.91 t/ha) or 2 : 1 (1.96 t/ha) row proportion was 16.9% and 20.1% (significantly), respectively, higher than sole crop of canola oilseed rape.

Stover yield of all component crops decreased significantly in the intercropping system compared to their respective sole crop except of Indian rape in Ethiopian mustard + Indian rape (1:2) at 22.5 cm row spacing (Table 2). Higher plant population of Ethiopian mustard in narrow row spacing (30 cm) resulted in its higher stover yield than wider row spacing (45 cm), whereas in the intercropping system, better expression of growth at wider row spacing (30 cm) after harvesting of Indian mustard resulted in its significantly higher stover yield than 22.5 cm row spacing.

Oil content in oilseed rape was higher than Indian rape and Ethiopian mustard (Table 2). The oil content of sole crop of Indian rape was significantly higher than its intercropping with canola oilseed rape (2 : 1) and Ethiopian mustard (1:1) at 30 cm row spacing. The oil content of oilseed rape in canola oilseed rape + Indian rape (2 : 1, 30 cm row spacing) was significantly higher than canola oilseed rape + Indian rape (1 : 1, 22.5 cm row spacing). Oil content among different treatments of Ethiopian mustard did not differ.

The land equivalent ratio for non-canola oilseed rape + Indian rape in 1 : 1 row ratio at 22.5 cm row spacing (1.40), canola oilseed rape + Indian rape in 1 : 1 or 2 : 1 row ratio at 22.5 cm row spacing (1.27, 1.29) and Ethiopian mustard + Indian rape in 1 : 2 row ratio at 22.5 cm row spacing (1.25) were substantially higher than other intercropping systems (Table 2). Yield advantage of intercropping of non-canola oilseed rape with Indian rape has been reported earlier to differences in growth pattern/ peak period of growth of these 2 component crops (Gutpa *et al.,* 1989).

Sole crop of Ethiopian mustard (30 cm row spacing) resulted in the highest net returns among all the intercropping systems (Table 2). Intercropping of non-canola oilseed rape with Indian rape resulted in higher net returns than its sole crop. Among canola oilseed rape-based intercropping systems, canola oilseed rape + Indian rape in 1 : 1 or 2 : 1 row ratio at 22.5 cm row spacing resulted in higher net income than sole canola oilseed rape.

The present investigation revealed that canola and non-

Table 2. Effect of intercropping systems on seed yield (kg/ha), stover yield (kg/ha), oil content, land-equivalent ratio and net returns of component crops

Treatment	Seed yield (t/ha)			Oilseed rape-equivalent yield (t/ha)	Stover yield (t/ha)			Oil content (%)			Land-equivalent ratio	Net returns (× 10³/ha)
	IR	OR	EM		IR	OR	EM	IR	OR	EM		
Canola oilseed rape + Indian rape at 22.5 cm (1:1)	1.08	0.85	-	1.91	4.04	3.72	-	41.4	41.0	-	1.27	38.0
Canola oilseed rape + Indian rape at 22.5 cm (2:1)	0.97	1.02	-	1.96	3.18	4.84	-	41.3	42.3	-	1.29	38.1
Canola oilseed rape + Indian rape at 30 cm (2:1)	0.62	1.20	-	1.81	2.58	6.20	-	40.8	43.6	-	1.17	37.5
Ethiopian mustard + Indian rape at 22.5 cm (1:1)	1.05	-	1.09	2.12	3.96	-	4.19	41.7	-	38.9	1.22	43.6
Ethiopian mustard + Indian rape at 30 cm (1:1)	1.01	-	1.20	2.18	3.86	-	5.90	40.8	-	38.2	1.23	50.2
Ethiopian mustard + Indian rape at 22.5 cm (2:1)	0.69	-	1.34	2.01	3.19	-	5.94	41.1	-	38.5	1.07	40.4
Ethiopian mustard + Indian rape at 30 cm (2:1)	0.65	-	1.59	2.22	2.53	-	6.66	41.1	-	38.5	1.16	50.6
Ethiopian mustard + Indian rape at 22.5 cm (1:2)	1.16	-	0.98	2.11	4.27	-	3.67	41.6	-	37.7	1.25	45.5
Non-canola oilseed rape + Indian rape at 22.5 cm (1:1)	1.03	1.27	-	2.27	3.23	6.31	-	41.7	41.8	-	1.40	49.1
Canola oilseed rape at 45 cm	-	1.63	-	1.63	-	9.61	-	-	41.9	-	1.00	34.6
Ethiopian mustard at 30 cm	-	-	2.24	2.25	-	-	9.79	-	-	37.8	1.00	52.7
Ethiopian mustard at 45 cm	-	-	2.15	2.15	-	-	9.55	-	-	38.1	1.00	50.7
Non-canola oilseed rape at 45 cm	-	1.85	-	1.85	-	12.87	-	-	42.0	-	1.00	44.7
Indian rape at 30 cm	1.44	-	-	1.41	4.80	-	-	41.9	-	-	1.00	24.6
SEm±	0.07	0.05	0.08	0.10	0.29	0.37	0.41	0.3	0.9	0.7	0.6	2.6
CD (P=0.05)	0.16	0.12	0.17	0.21	0.61	0.84	0.90	0.7	2.1	NS	0.13	5.6

IR, Indian rape; OR, oilseed rape; EM, Ethiopian mustard

canola oilseed rape were more compatible with Indian rape than Ethiopian mustard. Oilseed rape-based intercropping system resulted in higher oilseed rape-equivalent yield and net returns than sole crop of oilseed rape. The component crops performed better at 2 : 1 than 1 : 1 row ratio in the intercropping system. Higher productivity of oilseeds and economic returns can thus, be obtained by simultaneous sowing of oilseed rape (canola/non canola) and Indian rape in 1 : 1 or 2 : 1 row ratio at row spacing of 22.5 cm.

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