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Quality of component crops as influenced by intercropping of canola oilseed rape (*Brassica napus*) and Ethiopian mustard (*Brassica carinata*) with Indian rape (*Brassica rapa* var. Toria)

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Abstract

A field experiment was conducted at Punjab Agricultural University, Ludhiana during *rabi* 2014-15 to study the effect of different row proportions and row spacing of component crops in intercropping system on quality of canola oilseed rape (*Brassica napus*), Ethiopian mustard (*Brassica carinata*) and Indian rape (*Brassica rapa*). The experiment comprising, 14 treatments was conducted in randomized complete block design with three replications. Indian rape matured at 94 days after sowing whereas both oilseed rape and Ethiopian mustard matured at 164 days after sowing. Differences in seed oil content in Indian rape and oilseed rape were significant but seed protein content of all crops were non significant. Oil and protein yield of component crops though decreased in intercropping, the total oil yield and protein yield of both canola and non canola oilseed rape were significantly higher than their respective sole crop yields. Total oil and protein yields of Ethiopian mustard sown as sole crop or intercrop were comparable. Fatty acid composition of oil of only oilseed rape was influenced by intercropping.

Key words: *Fatty acid, intercropping systems, oil content, protein content, quality*

Introduction

Vegetable oils are important sources of energy, essential fatty acids (linoleic and linolenic) and carriers of fat soluble vitamins such as A, D, E and K. These oils also contribute to taste, flavour, palatability and satiety of food. Rapeseed-mustard is an important group of crops among different oilseed crops in India next only to soybean with a share of 22.2 per cent in total area under oilseeds and 22.6 per cent in total oilseeds production (Kumar, 2014). The oil of rapeseed-mustard is used in diverse ways such as for cooking, baking, lubricant, industry, tannin, soap, lamp oil, hair oil, medicines and most recently as biofuel. Rapeseed-mustard oil with a share of 26 per cent is the largest consumed oil in the country amongst domestically produced edible oils.

Quality of oil is determined by its fatty acid composition. In addition to amount of intake of edible oils, the consumers are becoming more and more aware about the importance of quality of oil being consumed in daily diet. Consequently the demand of vegetable oil low in saturated fats and those containing anti-oxidants and anti cholesterol properties is increasing (Kumar *et al.*, 2014). Rapeseed-mustard oil containing low amount of saturated fatty acids (<10%) and desirable amounts of mono- and poly- unsaturated fatty acids including essential fatty acids, antioxidants and vitamin E is considered as one of the healthiest edible oil. Seed meal after oil extraction is used as protein rich feed for livestock. Traditional cultivars of rapeseed-mustard, however, contain high levels of erucic acid in oil and glucosinolates in de-oiled seed meal which restrict the use of oil for humans and seed meal for livestock. The demand of canola (double zero) rapeseed-mustard which is free from erucic acid (<2 per cent) and possesses higher oleic acid (>60 per cent) content in oil and low concentration of glucosinolates in seed meal (<30 µmoles per gram defatted seed meal) is increasing as these are nutritionally superior to conventional non canola cultivars which contain higher concentration of erucic acid (40-50%) in oil and glucosinolates (>100 µmoles per gram) in defatted seed meal. Ethiopian mustard (*Brassica carinata)* is gaining importance in several parts of the world as a potential crop for biofuel production (Taylor *et al.*, 2010).

The demand of edible oils in the country is increasing at the rate of 4-6% per annum due to increase in population, improved income levels, purchasing power, living standards, changing food habits and increasing awareness about health benefits of vegetable oils/fats (Rao, 2009; Hegde, 2009). There is thus need to increase production of vegetable oils in the country which at present in less than 50% of the domestic minimum needs (Kumar, 2015). With limited scope of horizontal expansion (area increase) of oilseeds, the increased production has to be achieved from vertical expansion (intercropping) and improvement in productivity of these crops. Rapeseed-mustard group of oilseed crops are widely adapted to different agro-climatic zones of India and are often intercropped with different crops (Sahota and Saini, 1989; Sardana and Sidhu, 1997; Srivastava *et al.*, 2008). The present investigation was carried out to study the effect of intercropping of Indian rape on quality of recently developed canola quality oilseed rape and dwarf, determinate Ethiopian mustard.

Materials and Methods

The field experiment was conducted at the Oilseeds Section, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana during *rabi* 2014-15 on loamy sand soil of neutral pH (7.2-7.6) and free from salts (EC 0.12-0.18 dS/m). The soil tested low in organic carbon content (0.28, 0.16%) and potassium permanganate available nitrogen (188, 97 kg/ha), rich in Olsen's available phosphorus (28, 25 kg/ha) and medium in $NaHCO_3$ extractable available potassium (148, 196 kg/ha) at the depths of 0-15 cm and 15-30 cm, respectively.

The experiment comprised 14 treatments which were replicated thrice as per randomized complete block design. The test varieties 'TL 17' of Indian rape; 'GSC 7' of canola oilseed rape, 'GSL 1' of non canola oilseed rape and 'BJC13-4' of Ethiopian mustard were sown in different row proportions and row spacing as per treatments (Tables 1-3) on 18 September, 2014 by using recommended seed rates. Except for treatments, all the recommended agronomic practices were adopted to raise the crop. Fertilizers urea, single super phosphate and muriate of potash were applied to supply nitrogen (62.5 kg/ha to Indian rape and 100 kg/ha to oilseed rape and Ethiopian mustard), phosphorus (20 kg P_2O_5/ha to Indian rape and 30 kg P_2O_5/ha to oilseed rape and Ethiopian mustard) and potassium (15 kg K_2O/ha to oilseed rape and Ethiopian mustard), respectively. In intercropping, these nutrients were applied on area basis. In case of Indian rape, entire quantity of fertilizers was applied at sowing whereas in oilseed rape and Ethiopian mustard (sole crop) and in the intercropping systems (ICS) entire quantity of phosphorus and potassium, and 50% of N was also applied at time of field preparation before last planking. The remaining dose of N was applied to oilseed rape and Ethopian mustard after first irrigation and after harvesting of Indian rape. In the ICS, Indian rape was harvested in second fortnight of December, while oilseed rape and Ethiopian mustard were harvested in first fortnight of March.

The oil content in seed was determined with MQC benchtop Nuclear Magnetic Resonance (NMR) Analyser (Oxford instruments, UK) by using non-destructive method of oil estimation as suggested by Alexander *et al.* (1967). Protein content in seed was determined directly by multiplying the nitrogen content in the seed by a factor of 6.25. Oil and protein yields were calculated by multiplying the oil content and the protein content in the seed sample of each treatment with its respective seed yield. Fatty acids in oil were trans-esterified and analyzed by gas liquid chromatography (GLC) using standard method of trans-esterification developed by Appleqvist (1968). Analysis of variance was conducted for various parameters using computer programme CPCS1 (Cheema and Singh, 1991).

Table 1. Effect of intercropping systems on oil content, protein content, oil yield and protein yield of component crops

Treatments	Oil content (%)			Protein content (%)			Oil yield (kg/ha)				Protein yield (kg/ha)			
	*IR	*OR	*EM	*IR	*OR	*EM	*IR	*OR	*EM	Total	*IR	*OR	*EM	Total
Canola oilseed rape + Indian rape at 22.5 cm (1:1)	41.4	41.0	-	15.9	15.1	-	447	350	-	797	172	129	-	301
Canola oilseed rape + Indian rape at 22.5 cm (2:1)	41.3	42.3	-	15.8	15.2	-	399	432	-	831	153	154	-	307
Canola oilseed rape + Indian rape at 30 cm (2:1)	40.8	43.6	-	16.0	15.5	-	252	525	-	777	98	187	-	285
Ethiopian mustard + Indian rape at 22.5 cm (1:1)	41.7	-	38.9	15.7	-	14.9	440	-	424	864	165	-	163	328
Ethiopian mustard + Indian rape at 30 cm (1:1)	40.8	-	38.2	16.0	-	14.9	410	-	457	867	161	-	178	339
Ethiopian mustard + Indian rape at 22.5 cm (2:1)	41.1	-	38.5	15.7	-	15.1	284	-	513	797	109	-	202	311
Ethiopian mustard + Indian rape at 30 cm (2:1)	41.1	-	38.5	15.9	-	14.9	266	-	610	876	103	-	236	339
Ethiopian mustard + Indian rape at 22.5 cm (1:2)	41.6	-	37.7	15.9	-	15.1	483	-	371	854	185	-	148	333
Oilseed rape + Indian rape at 22.5 cm (1:1)	41.7	41.8	-	15.7	15.3	-	429	531	-	960	161	197	-	358
Canola oilseed rape at 45 cm	-	41.9	-	-	15.3	-	-	683	-	683	-	249	-	249
Ethiopian mustard at 30 cm	-	-	37.8	-	-	14.9	-	-	849	849	-	-	334	334
Ethiopian mustard at 45 cm	-	-	38.1	-	-	15.0	-	-	819	819	-	-	322	322
Oilseed rape at 45 cm	-	42.0	-	-	15.0	-	-	776	-	776	-	277	-	277
Indian rape at 30 cm	41.9	-	-	15.8	-	-	605	-	-	605	227	-	-	227
CD (P=0.05)	0.7	2.1	NS	NS	NS	NS	62	59	78	91	24	18	32	37

*IR = Indian rape, OR = Oilseed rape,EM = Ethiopian mustard

Results and Discussion

Oil and protein content

Different treatments significantly influenced the seed oil content of Indian rape and oilseed rape but not of Ethiopian mustard (Table 1). Seed oil content of oilseed rape (41.0 to 43.6%) was higher than Indian rape (40.8 to 41.9%) and Ethiopian mustard (37.7 to 38.9%). In case of Indian rape, the highest oil content (41.9%) obtained from sole crop was significantly higher than that from its intercropping with canola oilseed rape (2:1, 30 cm row spacing) and with Ethiopian mustard (1:1, 30 cm row spacing). In case of oilseed rape, the highest oil content (43.6%) registered with canola oilseed rape + Indian rape sown at 30 cm row spacing in 2:1 row ratio was significantly higher than canola oilseed rape + Indian rape sown at 22.5 cm row spacing in 1:1 row ratio. Similar differences in oil content among *Brassica* species (*B. napus, B. carinata, B. juncea*) have been reported by several workers (Prakash *et al.*, 1999; Kumar *et al.*, 2002; Rana, 2002). Seed protein content of all the test crops was not influenced by different intercropping systems and it varied within a narrow range of 15.7 to 16.0 per cent in Indian rape, 15.0 to 15.5 per cent in oilseed rape and 14.9 to 15.1 per cent in Ethiopian mustard (Table 1). Singh and Gupta (1994) also reported similar findings for Indian mustard in wheat + Indian mustard ICS.

Oil and protein yield

The oil yield of sole crop of Indian rape (605 kg/ha) was significantly higher (25.2 - 140.7%) over its yield under different ICS (Table 1). In canola oilseed rape based ICS, the oil yield of Indian rape in canola oilseed rape + Indian rape sown at 22.5 cm row spacing in 1:1 and 2:1 row proportion was similar (447, 399 kg/ha) but significantly higher than intercropping of canola oilseed rape + Indian rape at 30 cm row spacing in 2:1 row proportion (252 kg/ha). In Ethiopian mustard based ICS, the highest oil yield of Indian rape (483 kg/ha) was obtained from Ethiopian mustard + Indian rape sown at 22.5 cm row spacing in 1:2 row proportion whereas Ethiopian mustard + Indian rape sown at 30 cm row spacing in 2:1 row proportion resulted in lowest oil yield (266 kg/ha) of Indian rape. In case of oilseed rape, non canola oilseed rape (777 kg/ha) produced significantly higher oil yield than canola oilseed rape (683 kg/ha) and both these treatments out yielded all ICS by significant margin. Similarly oil yield from sole crop of Ethiopian mustard (819, 849 kg/ha) was significantly higher than its oil yield under different ICS. In the Ethiopian mustard based ICS, Ethiopian mustard + Indian rape in 2:1 row proportion at 30 cm row spacing resulted in highest oil yield (610 kg/ha) of Ethiopian mustard whereas the lowest oil yield (371 kg/ha) was obtained from Ethiopian mustard + Indian rape in 1:2 row proportion at 22.5 cm row spacing. Total oil yield from intercropping of non canola oilseed rape with Indian rape was significantly higher (25.0%) than sole crop of non canola oilseed rape (776 kg/ha). Similarly, intercropping of canola oilseed rape with Indian rape in different row proportions and spacing resulted in conspicuously higher (13.7 – 21.6%) oil yield as compared to sole crop of canola oilseed rape (683 kg/ha), with highest increase obtained from canola oilseed rape + Indian rape (2:1 row ratio at 22.5 cm row spacing). Intercropping of Ethiopian mustard with Indian rape resulted in 6.1% lower oil yield in 2:1 row proportion at 22.5 cm row spacing and marginal increase of 0.5 to 3.1% in other intercropping combinations as compared to sole crop of Ethiopian mustard.

Differences in seed protein yield among different treatments were significant in all the component crops (Table 1). Sole crop of Indian rape produced significantly higher protein yield (227 kg/ha) whereas intercropping of canola oilseed rape with Indian rape at 30 cm row spacing in 2:1 row proportion resulted in lowest protein yield of Indian rape (99 kg/ha). Among canola oilseed rape based ICS, protein yield of Indian rape in canola oilseed rape + Indian rape (1:1 and 2:1 at 22.5 cm row spacing) was significantly higher than canola oilseed rape + Indian rape in 2:1 at 30 cm row spacing. Similarly in case of Ethiopian mustard based ICS, the highest protein yield of Indian rape (185 kg/ha) obtained from Ethiopian mustard + Indian rape in 1:2 row ratio at 22.5 cm row spacing was significantly higher than Ethiopian mustard + Indian rape in 2:1 row ratio at both 22.5 cm and at 30 cm row spacing. Seed protein yield of sole crop of non canola oilseed rape

Table 2. Effect of intercropping systems on the fatty acid composition (%) of Indian rape

Treatments	Fatty acid composition (%)						
	Palmitic (16:0)	Stearic (18:0)	Oleic (18:1)	Linoleic (18:2)	Lino-lenic (18:3)	Eicos-enoic (20:1)	Erucic (22:1)
Canola oilseed rape + Indian rape at 22.5 cm (1:1)	2.6	0.80	9.9	14.4	11.8	4.3	54.0
Canola oilseed rape + Indian rape at 22.5 cm (2:1)	2.0	0.83	9.7	14.0	12.7	1.6	51.2
Canola oilseed rape + Indian rape at 30 cm (2:1)	2.3	0.80	9.7	14.6	10.7	4.90	52.7
Oilseed rape + Indian rape at 22.5 cm (1:1)	2.3	0.97	10.9	14.4	12.1	3.7	52.3
Ethiopian mustard + Indian rape at 22.5 cm (1:1)	2.4	0.80	10.7	14.4	10.4	4.9	52.9
Ethiopian mustard + Indian rape at 30 cm (1:1)	2.2	0.80	10.4	14.4	10.9	4.6	52.7
Ethiopian mustard + Indian rape at 22.5 cm (2:1)	2.1	0.80	10.0	15.0	10.5	4.4	53.3
Ethiopian mustard + Indian rape at 30 cm (2:1)	2.4	0.83	10.2	14.7	13.8	2.2	52.7
Ethiopian mustard + Indian rape at 22.5 cm (1:2)	2.2	0.90	10.5	14.1	11.8	3.3	53.8
Indian rape at 30 cm	3.0	1.00	10.4	14.0	10.9	3.9	54.0
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 3. Effect of intercropping systems on the fatty acid composition (%) of oilseed rape

Treatments	Fatty acid composition (%)						
	Palmitic (16:0)	Stearic (18:0)	Oleic (18:1)	Linoleic (18:2)	Lino-lenic (18:3)	Eicos-enoic (20:1)	Erucic (22:1)
Canola oilseed rape + Indian rape at 22.5 cm (1:1)	4.47	1.53	63.80	16.70	9.43	1.83	0.93
Canola oilseed rape + Indian rape at 22.5 cm (2:1)	4.40	1.47	63.37	16.20	9.23	2.60	1.67
Canola oilseed rape + Indian rape at 30 cm (2:1)	4.37	1.53	66.13	16.70	9.03	0.93	0.10
Canola oilseed rape at 45 cm	4.30	1.57	65.07	15.93	9.00	1.87	0.77
Oilseed rape + Indian rape at 22.5 cm (1:1)	3.57	1.17	17.13	15.37	9.97	10.87	39.20
Oilseed rape at 45 cm	3.40	1.13	17.00	14.63	9.63	10.37	40.73
CD (P=0.05)	0.30	0.19	4.06	0.80	NS	1.35	2.20

Table 4. Effect of intercropping systems on the fatty acid composition (%) of Ethiopian mustard

Treatments	Fatty acid composition (%)						
	Palmitic (16:0)	Stearic (18:0)	Oleic (18:1)	Linoleic (18:2)	Lino-lenic (18:3)	Eicos-enoic (20:1)	Erucic (22:1)
Ethiopian mustard + Indian rape at 22.5 cm (1:1)	3.97	1.03	16.77	19.97	14.97	10.17	28.80
Ethiopian mustard + Indian rape at 30 cm (1:1)	3.97	1.07	16.93	19.87	15.03	10.80	28.80
Ethiopian mustard + Indian rape at 22.5 cm (2:1)	4.03	1.00	16.43	20.67	15.20	10.00	28.73
Ethiopian mustard + Indian rape at 30 cm (2:1)	4.13	1.10	16.33	20.26	14.77	10.70	28.73
Ethiopian mustard + Indian rape at 22.5 cm (1:2)	3.93	1.13	17.13	20.43	14.77	10.33	28.57
Ethiopian mustard at 30 cm	4.07	1.10	17.07	20.60	14.53	10.10	28.67
Ethiopian mustard at 45 cm	3.90	1.07	16.87	19.13	15.13	10.40	29.60
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

(277 kg/ha) was significantly higher than sole crop of canola oilseed rape (249 kg/ha) and intercropping of non canola oilseed rape with Indian rape (197 kg/ha). Similarly seed protein yield of sole crop of canola oilseed rape was significantly higher than its yield under different ICS. Among different Ethiopian mustard based ICS, sole crop of Ethiopian mustard produced significantly higher seed protein yield than its yield under different ICS (Table 1). The seed protein yield (236 kg/ha) obtained from Ethiopian mustard + Indian rape in 2:1 row ratio at 30 cm row spacing was significantly higher than other Ethiopian mustard based ICS. Total protein yield of non canola oilseed rape + Indian rape ICS (358 kg/ha) was significantly higher (29.4%) than sole crop of non canola oilseed rape. Intercropping of canola oilseed rape with Indian rape in different row proportions also significantly increased the total protein yield by 14.4 to 23.2% over sole canola oilseed rape (249 kg/ha). The total protein yield of sole crop of Ethiopian mustard (322, 334 kg/ha) was comparable with different Ethiopian mustard based ICS (311-339 kg/ha). Oil and protein yield were mainly influenced by seed yield. Protein yield of sole crops was higher than their respective yield in the ICS owing to their higher seed yield as the differences in seed protein content among different treatments were inconspicuous.

Fatty acid composition

Fatty acid composition of Indian rape (Table 2) and Ethiopian mustard (Table 4) was not influenced by intercropping treatments. Differences in fatty acid composition of oilseed rape were, however, significant except for linolenic acid content (Table 3). Canola oilseed rape contained significantly higher palmitic-, stearic-, oleic- and linoleic- acid content and significantly lower eicosenoic- and erucic- acid content than non canola oilseed rape. However, fatty acid profile of canola or non canola oilseed rape grown as intercrop or sole crops was similar. Nayyar and Sardana (2010) reported similar differences in fatty acid composition of canola and non canola cultivars of oilseed rape.

Conclusion

Seed oil content of Indian rape and oilseed rape was significantly influenced by different intercropping treatments whereas oil content of Ethiopian mustard and seed protein content of all crops remained unaffected by different intercropping systems. Oil and protein yield of component crops though decreased in intercropping in proportion to row ratio and row spacing, total oil yield and protein yield of both canola and non canola oilseed rape were, however, significantly higher than their respective sole crop yields. Total oil and protein yields of Ethiopian mustard sown as sole crop or intercrop were comparable. Fatty acid composition of oil of only oilseed rape was influenced by different treatments and species in intercropping.

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