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Intercropping of menthol mint (*Mentha arvensis* L.) and spearmint (*Mentha spicata* L.) with sugarcane (*Saccharum officinarum* L.)

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Abstract

Field experiments were conducted at Lucknow (Uttar Pradesh), to study the effect of two sugarcane (*Saccharum officinarum*) cultivars namely, Co-S 767 (early, profuse tillering) and Co-Lk 8001 (late, shy tillering) and two planting geometries namely, 90 cm interval regular rows and 75 cm (row-to-row distance within the pair) x 120 cm (distance between two pairs of rows) paired rows for maximizing productivity, land use efficiency and income benefits through raising of menthol mint (*Mentha arvensis*) or spearmint (*Mentha spicata*) as intercrops in main as well as ratoon crop of sugarcane. As a sole crop, the two sugarcane cultivars were equally productive during the main crop cycle but during the ratoon crop cycle cv. Co-S 767 yielded 15.3% more cane than cv. Co-Lk 8001. Sugarcane cv. Co-S 767 in paired row planting showed no reduction in cane yield by mint intercropping compared to 16.2% to 28.1% reduction in regular row planting during both main and ratoon crop cycles. Sugarcane cv. Co-Lk 8001, however, did not suffer yield reduction by mint intercropping, irrespective of methods of sugarcane planting and crop cycles. However, menthol mint and spearmint suffered yield reduction (52% to 75%) as intercrops compared to their respective sole crop yields. In general, mint oil yield reductions were more during the ratoon crop cycle and when the companion crop was cv. Co-S 767. Mint intercropping with sugarcane cv. Co-Lk 8001 significantly improved land use efficiency (23% to 35%), gross (29% to 46%) and net returns (90% to 137%) and benefit-cost ratio (44% to 63%). Interplanting spearmint with sugarcane cv. Co-Lk 8001 resulted in maximum profits.

Key words: intercropping, *Mentha arvensis*, *Mentha spicata*, menthol mint, *Saccharum officinarum*, spearmint, sugarcane.

Introduction

Sugarcane (*Saccharum officinarum* L.) offers good scope for intercropping in India due to its planting at wide (≥ 90 cm) spacing and slow initial growth. Successful intercropping of cereals (Yadav & Prasad 1991), legumes (Laclezio *et al.* 1985), oil seeds (Yadav & Singh 1989), vegetables (Patil *et al.* 1991), spices (Verma & Yadav 1988) and mints (Kothari *et al.* 1987a, b) in sugarcane has been demonstrated earlier.

Integration of medicinal and aromatic plants such as menthol mint (*Mentha arvensis* L.) and spearmint (*Mentha spicata* L.) with sugarcane

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may have several advantages for utilization of limited agricultural resources in addition to production of high value raw materials for pharmaceuticals, agrochemicals and cosmetic industries (Kumar *et al.* 2001). Since there is paucity of information on the possibilities of mint intercropping in the main as well as the ratoon crop of sugarcane, the present investigation was undertaken to study the effect of two sugarcane cultivars (Co-S 767, early and profuse tillering and Co-Lk 8001, late and shy tillering) and two planting geometries (regular vs. paired row) on spearmint or menthol mint as intercrop.

Materials and methods

The field experiments were conducted during 1997–99 at the Research Farm of Central Institute of Medicinal and Aromatic Plants, Lucknow (Uttar Pradesh). The experimental location experiences a semi-arid subtropical climate and is situated at 26.5° N latitude, 80.5° E longitude at an altitude of 120 m MSL. The soil of the experimental site was sandy loam in texture, with a pH of 7.9 and was categorized as low in available N (85 kg ha^{-1}) and medium in available P (13.7 kg ha^{-1}) and K (167 kg ha^{-1}). The treatments comprised of intercropping in regular (90 cm apart rows) and paired (75 cm apart within the pair x 120 cm apart between two pairs) row planting of two sugarcane cultivars (Co-S 767 and Co-Lk 8001) with menthol mint (cv. Kalka) or spearmint (cv. MSS-5). Additional sole crop treatments of both the cultivars of sugarcane and mint species were included for comparison. In the intercropping treatments, either two rows of mint species at 45 cm apart were accommodated between 90 cm spaced regular rows of sugarcane or three rows of mint species at 30 cm apart were accommodated between 120 cm spaced paired rows of sugarcane. For sole cropping treatments, sugarcane and either of the mint species were planted at a regular row-to-row spacing of 90 and 45 cm, respectively. The experiment was laid out in a randomised block design with 12 treatments and 4 replications; the individual plot size was 5.4 m x 4.0 m (21.6 m^2). The number of sugarcane rows in each plot was 6, irrespective of treatments; however, the number of mint rows in each plot was 12 in its sole cropping treatments, and 10 and 6 in its intercropping treatments on regular and paired rows of sugarcane, respectively.

Sole crop of sugarcane and mint received 120 kg N, 17.4 kg P and 30.8 kg K ha^{-1} while intercropping treatments received double the dose of all the three nutrients. The entire quantity of P and K in the form of single super phosphate and muriate of potash, respectively, were incorporated in the top 15 cm soil before planting. Nitrogen in the form of urea was however applied in three equal splits at 40, 80 and 120 DAP (days after planting) irrespective of treatments. An equivalent dose of N, P and K was also applied for the ratoon crop. Mint species and sugarcane were planted on 14 January and 10 February 1997, respectively. Rhizomes of menthol mint cv. Kalka and spearmint cv. MSS 5 and 2-3 budded sets of sugarcane cv. Co-S 767/Co-Lk 8001 were used for planting the respective crops. The intercrops menthol mint and spearmint were harvested twice i.e., 13 May 1997 and 11 July 1997 (first and second harvests) and 2 May 1997 and 1 July 1997 (first and second harvests), respectively.

Oil content in the green herb of mint was determined using essential oil distilling (Clevenger's) apparatus at the time of harvest and the individual plot biomass yield was recorded. Oil yield was computed using the corresponding data on biomass yield and oil content. Mint oil samples collected were analysed for quality parameters (*l*-menthol in menthol mint oil and carvone in spearmint oil) using a gas chromatograph (Perkin Elmer Model 3920 B) fitted with flame ionisation detector, stainless steel column of 2 m x 3 mm packed with 10% carbowax 20 M on chromosorb WAW (mesh size 80/100) at isothermal condition. Hydrogen flowing at the rate of 30 ml min^{-1} was used as carrier gas. Processor Vesta-401 attached with GC printed the relative percentages of the constituents. Identification of the essential oil constituents was accomplished by comparing retention times of the peaks with those of the reference compounds run under identical conditions, and Kovat's retention indices of the peaks with literature data (Ramaswamy *et al.* 1988; Davies 1990).

After the second harvest of mint, ridges were made for sugarcane followed by wrapping and propping to avoid lodging. Sugarcane was harvested on 17 January 1998 and data on milleable canes and cane yield were recorded. Juice recovery was calculated from five randomly selected canes from each plot and crushed in a three-roller electric cane crusher. The brix value (sugar content) was recorded using a Brix Hydrometer. Juice samples were mixed thoroughly and passed through a 150 mesh sieve and the filtrate was diluted to 1 l and allowed to settle for 15 min. The temperature of the juice was noted and brix value was corrected as per Spencer & Meade (1955). Land equivalent ratio (LER) as discussed by Mead & Willey (1980) has been shown to overestimate land use efficiency because of variability in duration of main and intercrop species (Hiebsch & Mc Collum 1987; Kothari *et al.* 1987a,b). Similarly, area time equivalency ratio (ATER) as proposed by Heibsch (1978) has been shown to underestimate land use efficiency (LUE) as it assumes that continuous crop production of intercrop species is possible with a constant yield potential in respect of time, which is seldom true. Hence, in this study, the LER overestimated and the ATER underestimated the LUE. Therefore, the average values of LER and ATER were considered for LUE than either the LER or ATER alone (Mason *et al.* 1986; Kothari *et al.* 1987b).

All the plots were manually cleaned after sugarcane harvest and hand hoeing was done to bring the soil to good tilth. Fertilizers (N, P and K) were mixed with the soil as per main crop cycle and mint species were replanted on 25 January 1998. The intercrops menthol mint and spearmint were harvested (ratoon crop cycle) on 24 May 1998 and 23 July 1998 (first and second harvests) and 16 May 1998 and 14 July 1998 (first and second harvests), respectively, and sugarcane was harvested on 25 January 1999. Data on mint and sugarcane were recorded during the ratoon crop cycle similar to main crop cycle.

Weeds were removed manually from each plot three times to avoid potential loss in yield during both main and ratoon crop cycles of sugarcane. Both mint and sugarcane were irrigated frequently (50% depletion of available soil moisture) during summer months.

All the data were subjected to statistical analysis using analysis of variance technique as applicable to randomised block design (Cochran & Cox 1959). The significance of treatment effects was tested using the variance (F) ratio test at 5% probability level.

Results and discussion

Milleable cane, yield and quality of sugarcane

The number of sugarcane sprouts counted 4 and 6 weeks after planting of sugarcane sets revealed that mint species did not influence sprouting of sugarcane. However, tillering of the emerged sugarcane plant 12 weeks after planting, exhibited significant reduction due to intercropping in main crop of sugarcane, particularly in cv. Co-S 767, with either of the mint species (data not shown here). In the intercropping treatments, there was no evidence of the plants experiencing stress due to water or nutrient deficiencies.

Sugarcane cv. Co-Lk 8001 as the sole crop produced 27% and 43% less milleable canes in main and ratoon crops, respectively, compared to the sole crop of Co-S 767 (Table 1). However, single cane weight of cv. Co-Lk 8001 was 33.8% and 51.7% more than Co-S 767 in the main and ratoon crop cycles, respectively, due to higher cane length and girth (data not shown here). Sugarcane cv. Co-S 767 in paired row planting showed no reduction in number of milleable canes by mint intercropping contrary to 17.2% to 32.3% reduction in regular row planting during both the crop cycles (Table 1). Sugarcane cv. Co-Lk 8001, however, did not show reduction in number of milleable cane, by mint intercropping, irrespective of methods of sugarcane planting and crop cycles.

Table 1. Yield and quality of sugarcane as influenced by mint intercropping

Treatment	No. of milleable cane m^{-2}		Cane yield (t ha^{-1})		Juice recovery (%)		Brix value	
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
S. cane Co-S 767	13.9	12.8	98.7	74.0	51.3	51.1	21.5	22.1
S. cane Co-Lk 8001	10.1	7.3	95.8	64.2	60.7	59.3	21.6	22.3
S. cane Co-S 767 (regular) + M. mint	10.0	10.1	73.0	60.2	49.2	49.2	21.3	21.8
S. cane Co-S 767 (regular) + S. mint	9.4	10.6	71.0	62.0	50.4	50.2	21.2	22.4
S. cane Co-S 767 (pair) + M. mint	12.8	12.1	91.2	67.5	50.6	51.3	21.7	21.8
S. cane Co-S 767 (pair) + S. mint	12.5	11.6	92.0	68.1	51.4	52.4	21.5	22.6
S. cane Co-Lk 8001 (regular) + M. mint	8.8	6.3	86.0	61.3	58.1	59.2	22.4	22.5
S. cane Co-Lk 8001 (regular) + S. mint	8.9	7.0	103.0	65.0	59.3	60.1	22.1	22.1
S. cane Co-Lk 8001 (pair) + M. mint	9.1	6.1	91.0	69.2	59.3	58.8	22.1	22.9
S. cane Co-Lk 8001 (pair) + S. mint	9.2	7.1	107.0	67.1	59.9	58.6	22.3	22.5
CD (P=0.05)	1.4	1.3	11.2	7.5	6.5	6.1	NS	NS

S. cane=sugarcane; M. mint=menthol mint (cv. Kalka); S. mint=spearmint (cv. MSS-5)

Regular planted sugarcane cv. Co-S 767 suffered yield reductions of 16.2% to 28.1% in the intercropping systems contrary to cv. Co-Lk 8001. The cane yield was, however, not influenced by mint intercropping in the paired row system for either cultivar of sugarcane and crop cycle.

The juice recovery of sugarcane cv. Co-Lk 8001 was higher than that of sugarcane cultivar cv. Co-S 767. However, the brix value of both the cultivars of sugarcane showed no significant variations. In both cultivars of sugarcane, mint interplanting did not significantly influence either juice recovery or brix value.

Biomass, oil yield and oil quality of mints

Menthol mint as an intercrop, both during main and ratoon crop cycles of sugarcane, gave only one harvest instead of two harvests under sole cropping. Spearmint, as an intercrop during the main crop cycle of sugarcane, gave two harvests, as obtained under sole cropping. However, during the ratoon crop cycle, spearmint as an intercrop gave only one harvest, as for menthol mint. Both the mints grew taller as intercrops compared to sole crop particularly during the main crop cycle of sugarcane (data not shown). Despite increased height, biomass yield of both the mint species reduced significantly under intercropping compared to sole cropping, both during the main and the ratoon crop cycles of sugarcane (Table 2). The biomass yield reduction due to intercropping was more during the ratoon cycle than during the main cycle. Considering total biomass production during the main and ratoon crop cycles, the mint biomass yield reduction in various intercropping treatments ranged between 45.7% and 71.0%, compared to sole cropping of mint species. Spearmint intercropping of regular planted sugarcane cv. Co-Lk 8001 gave the maximum total biomass yield among the intercropping treatments. As intercrop, menthol mint suffered essential oil yield reductions of 52.2% to 72.5% as against 55.1% to 75.0% in spearmint compared to their respective sole crop yields. Mint oil yield was

Table 2. Biomass and mint oil yield as influenced by intercropping systems

Treatment	Biomass yield (t ha^{-1})			Mint oil yield (kg ha^{-1})		
	Plant cane	Ratoon cane	Total	Plant cane	Ratoon cane	Total
M. mint	25.9	26.4	52.3	164.2	173.0	337.2
S. mint	29.9	21.1	51.0	190.8	172.4	363.2
S. cane Co-S 767 (regular) + M. mint	16.0	4.0	20.0	86.4	20.4	106.8
S. cane Co-S 767 (regular) + S. mint	20.1	3.9	24.0	103.7	25.0	128.7
S. cane Co-S 767 (paired) + M. mint	10.1	5.5	15.6	60.6	32.0	92.6
S. cane Co-S 767 (paired) + S. mint	12.3	2.5	14.8	73.4	17.5	90.9
S. cane Co-Lk 8001 (regular) + M. mint	18.2	9.1	27.3	112.8	48.2	161.0
S. cane Co-Lk 8001 (regular) + S. mint	23.5	4.2	27.7	132.9	30.0	162.9
S. cane Co-Lk 8001 (paired) + M. mint	12.7	7.2	19.9	81.2	38.9	120.1
S. cane Co-Lk 8001 (paired) + S. mint	15.0	3.0	18.0	93.4	21.9	115.3
CD (P=0.05)	2.8	1.2	4.0	12.5	4.5	17.0

S. cane=sugarcane ; M. mint=menthol mint (cv. Kalka); S. mint=spearmint (cv. MSS-5)

markedly reduced during the ratoon crop cycle especially when the companion crop was cv. Co-S 767. The maximum oil yield of menthol mint and spearmint as intercrops was recorded in the treatment mint intercropping of regular planted sugarcane cv. Co-Lk 8001. The quality of menthol mint and spearmint oils as measured in terms of *l*-menthol (78.9% to 83.6%) and carvone (65.5% to 72.9%) contents respectively, did not vary appreciably between sole and intercropping systems.

Land use efficiency and economics

In general, LUE based on pooled data of main and ratoon crop cycles were more than 100% in all the intercropping treatments indicating higher land use efficiency under intercropping (Table 3). Further, LUE values were distinctly higher in the intercrop treatments involving sugarcane cv. Co-Lk 8001 than cv. Co-S 767. Maximum LUE was associated with the treatment of interplanting regular planted sugarcane cv. Co-Lk 8001 with spearmint. Similarly, mint intercropping in both the cultivars of sugarcane significantly improved gross return, net return and benefit-cost ratio and maximum increase of 64%, 172% and 107%, respectively, was obtained due to spearmint intercropping in regular planted sugarcane cv. Co-Lk 8001.

Under intercropping, paired row planting was advantageous compared to regular planting for both the cultivars of sugarcane and during both the crop cycles. This was because yield of paired row planted sugarcane cv. Co-S 767 or cv. Co-Lk 8001 did not suffer by mint intercropping probably due to 40% lower intercrop population (the number of mint rows were 6 and 10 in paired and regular method of sugarcane planting, respectively). Interplanting regular planted sugarcane cv. Co-S 767 with mint, however, reduced number of milleable canes by 17.2% to 32.3% and cane yield by 16.2% to 28.1% during both the main and ratoon crop cycles contrary to cv. Co-Lk 8001 (Table 1). This was because the number of milleable canes of regular planted sugarcane cv. Co-Lk 8001 was not affected due to mint intercropping unlike sugarcane cv. Co-S 767. The shy and late tillering characteristic of sugarcane cv. Co-Lk 8001 was the prime factor for the differential response of sugarcane cultivars. Yield of sugarcane cv. Co-Lk 8001 was on par with cv. Co-S 767 despite producing 27.3% lower number of milleable canes.

The quality of sugarcane measured in respect of juice recovery and brix value was not influenced due to mint intercropping of main and ratoon crop of sugarcane (Table 1). These results are in agreement with those of Sharma *et al.* (1992).

Both the mint species as intercrops gave maximum oil yield both in regular planted main as well as ratoon crop of sugarcane cv. Co-Lk 8001 (Table 2). The conditions for growth

Table 3. Land equivalent ratio and economics of sugarcane-mint intercropping system (pooled data of main and ratoon crop cycles)

Treatment	Land use efficiency (%)	Gross return* ('000 Rs ha^{-1})	Net return ('000 Rs ha^{-1})	Benefit : Cost ratio
S. cane Co-S 767	100	120	36	0.31
S. cane Co-Lk 8001	100	112	30	0.27
M. mint	100	108	38	0.35
S. mint	100	115	44	0.38
S. cane Co-S 767 (regular) + M. mint	101	123	41	0.33
S. cane Co-S 767 (regular) + S. mint	104	128	45	0.35
S. cane Co-S 767 (pair) + M. mint	111	136	50	0.37
S. cane Co-S 767 (pair) + S. mint	111	137	51	0.37
S. cane Co-Lk 8001 (regular) + M. mint	123	147	60	0.41
S. cane Co-Lk 8001 (regular) + S. mint	135	163	71	0.44
S. cane Co-Lk 8001 (pair) + M. mint	124	145	57	0.39
S. cane Co-Lk 8001 (pair) + S. mint	131	154	63	0.41
CD (P=0.05)	15	17	5	0.04

S. cane=sugarcane; M. mint=menthol mint (cv. Kalka); S. mint=spearmint (cv. MSS-5)
* Sale price: sugarcane - Rs. 900 t^{-1}; mint oil - Rs. 275 kg^{-1}

and yield of mints as intercrop was probably more favourable with shy and late tillering cv. Co-Lk 8001 compared to profuse and early tillering cv. Co-S 767. Furthermore, the number of mint rows per plot being higher in regular (10 rows) than in paired (6 rows) method, probably resulted in production of more mint oil due to intercropping of regular planted sugarcane. Mint oil production was more affected during ratoon crop cycle and when the companion was cv. Co-S 767, probably because of faster re-growth after harvest of cv. Co-S 767. Though yield losses were observed in various intercropping systems with menthol mint and spearmint as intercrops, *l*-menthol and carvone concentration in menthol mint and spearmint essential oil, respectively did not vary appreciably either by cropping systems or by planting geometry and cultivars of sugarcane.

Higher LUEs, gross and net returns and benefit-cost ratios with intercropping systems involving sugarcane cv. Co-Lk 8001 indicated substantial benefits because of less adverse effect of this cultivar of sugarcane on mint species (Table 3). Maximum LUE, gross and net returns and benefit-cost ratio was recorded in the treatment on intercropping regular planted sugarcane cv. Co-Lk 8001 with spearmint. This is because in this treatment spearmint as an intercrop not only produced highest essential oil among intercrop treatments but also had no adverse impact on growth and yield of sugarcane during both main and ratoon crop cycles. Paired row planting of sugarcane cv. Co-S 767 and interplanting it with either of the mint species was advantageous compared to regular planting. But such advantages were not obtained with sugarcane cv. Co-Lk 8001 because of its shy and late tillering characteristics.

Thus, it may be concluded that late and shy tillering sugarcane cv. Co-Lk 8001 performed better than early and profuse tillering Co-S 767 under intercropping systems. Interplanting regular planted sugarcane cv. Co-Lk 8001 with spearmint gave maximum yield and economic advantages. Paired row planting of sugarcane cv. Co-S 767 and its interplanting with either of the mint species was advantageous compared to regular planting. As intercrop, spearmint produced higher essential oil yield and was thus superior to menthol mint. The essential oil quality of menthol mint/spearmint grown as intercrops in sugarcane was similar to that of respective sole crops. Adoption of mint intercropping of sugarcane will benefit farmers in getting early returns (from sale of mint oil) besides generation of sizeable extra employment (about 100 man days ha^{-1}) and production of mint oil.

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