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Productivity and Biological Efficiency Indices of Sesamum + Cowpea Intercropping System in Response to Row Ratio and Nutrient Management

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***Abstract*:** Field experiment on sesamum + cowpea intercropping system was carried out to assess the yield advantage of the system using biological indices, *viz.,* land equivalent ratio (LER), relative crowding coefficient (RCC), aggressivity (A), competition index (CI), competition ratio (CR), sesamum equivalent yield (SEY) and percentage yield difference (PYD). The study was conducted at College of Agriculture, Vellayani, Thiruvananthapuram during the summer season of 2023. The experiment treatments comprised of combinations of three factors, *viz.,* three levels of nitrogen (N) (n_1- 100 % RDN; n_2- 75 % RDN; n_3- 50 % RDN), two row ratios (R) (r_1- 4:2; r_2- 6:3) and application of AMF (A) (a_1- without AMF; a_2- with AMF). The seed yield of sesamum and cowpea were significantly influenced by individual and interaction effects of treatments. Irrespective of the treatments applied all the intercropping systems showed advantage in terms of LER, CI and PYD. The component crop cowpea was observed with positive (+) aggressivity and higher (>1) CR indicates the dominance of cowpea over sesamum. The intercropping system with the treatment combination 100 % RDN at 6:3 row ratio without AMF ($n_1r_2a_1$) resulted in higher LER (2.40), RCC (66.18), SEY (1801), and PYD (139.87%).

Keywords: Sesamum intercropping, Biological indices, Productivity, Row ratio, AMF, levels of nitrogen

Sesamum stands as a traditionally significant and culturally influential crop with widespread impact on agriculture and nutrition. However, sesamum has been recognized as an exhaustive crop based on its ability to utilize and deplete soil nutrients at an accelerated rate, if not managed properly can lead to decline in soil fertility. Sesamum, being a crop highly susceptible to waterlogging, unprecedented rainfall is always a risk for sole cropping. Intercropping involving compatible crops is regarded as a risk alleviator with sustained yield advantage compared to sole cropping (Aulakh et al 2019). In general, pulses are perfect candidates for intercropping due to their short duration and relatively lower sensitivity to light and temperature. Further, they fix atmospheric nitrogen and also share a portion of the fixed nitrogen to the intercropped oilseeds (Jiwan et al 2021). Cowpea (*Vigna unguiculata* (L.) Walp) is one of pulses with high adaptability and consumer preference in Kerala. Several studies have shown cowpea to be a suitable crop for intercropping. However, cowpea is an aggressive legume and its performance in combination with sesamum has yielded contrasting results. Guedes et al (2010) reporting yield reduction of cowpea and Bhatti et al (2005) reporting reduction in yield of sesamum. Crop density and row configuration are important agronomic considerations for attaining the objectives of intercropping (Afe 2017). Both additive series and replacement series have been tested in several intercropping systems. With increasing demand for more sustainable crop production practices, supplying more nitrogen through nitrogen-fixation than by using synthetic chemical fertilizers has become a lucrative choice (Fustec et al 2010). Interplant nitrogen transfer, though a bi-directional process, nitrogen tends to get transferred from nitrogen-fixers to non-nitrogen fixers (Carlsson and Huss-Danell 2014). Arbuscular mycorrhizal fungi (AMF) are obligate symbionts that transport considerable amount of nutrients and water through the hyphal network to the associating crop (Chen et al 2018). This study therefore concentrates on the individual and interactive effects of various factors, *viz.,* nitrogen, row ratios, and AMF, on the productivity and biological efficiency of sesamum + cowpea intercropping system.

MATERIAL AND METHODS

The experiment conducted at, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India located at 8°25'41.3"N latitude and 76°59'16.7"E longitude, at an altitude of 29 m above mean sea level, during February to May 2023. The soil of the experimental field was sandy clay loam with a moderate acidic pH (5.8), moderate level of organic carbon (0.81%), low status of nitrogen (250.88 kg/ha), high availability of phosphorus (49.68 kg/ha), and medium in potassium (253.57 kg/ha) status. The sesamum variety

Thilak (ACV-3) released from College of Agriculture, Vellayani, Thiruvananthapuram and cowpea variety PGCP – 6 (Pant lobia - 3) released from G. B. pant University of Agriculture and Technology, Pantnagar were used for the study. The experiment was laid out in randomised block design with 3 x 2 x 2 treatments replicated thrice. The three factors were, levels of nitrogen (n_1- 100 % recommended dose of nitrogen (RDN); n_2- 75 % RDN; n_3- 50 % RDN), row ratios (r_1- 4:2; r_2- 6:3) and application of arbuscular mycorrhizal fungi (AMF) (a_1- without AMF; a_2- with AMF). All cultural practices followed as per the KAU package of practices recommendations (KAU 2016). Sole crops of sesamum and cowpea were raised for computing intercropping indices. The sesamum was harvested when the seeds of tenth capsule turned black and cowpea was harvested when 70 to 80 % of the pods turned brown with hard seeds inside. The sesamum and cowpea were harvested separately from the net plot area and the seeds were sun-dried and weight was expressed as seed yield in kg/ha. Biological indices were computed using yield data obtained from the intercropping system and sole crops.

Seed yield: Net plot area was harvested and the seeds were sun-dried and weight was expressed as seed yield in kg/ha.

Land equivalent ratio (LER): Land equivalent ratio was calculated as per the formula suggested by Willey (1979).

$$LER = L_s + L_c = \frac{Y_{sc}}{Y_{ss}} + \frac{Y_{cc}}{Y_{cs}}$$

where, L_s, L_c- LER for sesamum and cowpea, Y_{sc}- intercrop yield of sesamum

Y_{cs}- intercrop yield of cowpea, Y_{ss} - sole crop yield of sesamum

Y_{cc}- sole crop yield of cowpea

Relative crowding coefficient (RCC): Relative crowding coefficient denoted as 'K' was computed (de Wit 1960).

$$K_{sc} = \frac{Y_{sc} \times Z_{cs}}{(Y_{ss} - Y_{sc})Z_{sc}}$$

$$K_{cs} = \frac{Y_{cs} \times Z_{sc}}{(Y_{cc} - Y_{cs})Z_{cs}}$$

$$K = K_{sc} \times K_{cs}$$

where, K_{sc} and K_{cs}- relative crowding coefficient of sesamum intercropped with cowpea and sesamum, Y_{ss}- sole crop yield of sesamum, Y_{sc} - intercrop yield of sesamum , Y_{cc}- sole crop yield of cowpea, Y_{cs}- intercrop yield of cowpea

Z_{sc}- sown proportion of sesamum, Z_{cs}- sown proportion of cowpea

Aggressivity (A): Aggressivity was computed by using the formula proposed by McGilchrist (1965).

$$A_{sc} = \frac{Y_{sc}}{Y_{ss} \times Z_{sc}} - \frac{Y_{cs}}{Y_{cc} \times Z_{cs}} \qquad A_{cs} = \frac{Y_{cs}}{Y_{cc} \times Z_{cs}} - \frac{Y_{sc}}{Y_{ss} \times Z_{sc}}$$

where, A_{sc}- aggressivity of sesamum, A_{cs}- aggressivity of cowpea, Y_{ss}- sole crop yield of sesamum, Y_{cs} - intercrop yield of cowpea, Y_{cc}- sole crop yield of cowpea, Y_{sc}- intercrop yield of sesamum , Z_{sc}- sown proportion of sesamum, Z_{cs}- sown proportion of cowpea

Competition index (CI): Competition index was computed as suggested by Donald (1963).

$$CI = \frac{(Y_{ss} - Y_{sc}) \times (Y_{cc} - Y_{cs})}{Y_{ss} \times Y_{cc}}$$

where, Y_{ss}- sole crop yield of sesamum, Y_{sc}- intercrop yield of sesamum

Y_{cc}- sole crop yield of cowpea, Y_{cs}- intercrop yield of cowpea

Competition ratio (CR): Competition ratio was calculated (Willey et al 1980).

$$CR_s = \frac{Y_{sc}}{Y_{ss} \times Z_{sc}} \div \frac{Y_{cs}}{Y_{cc} \times Z_{cs}}$$

$$CR_c = \frac{Y_{cs}}{Y_{cc} \times Z_{cs}} \div \frac{Y_{sc}}{Y_{ss} \times Z_{sc}}$$

where,

CR_s, CR_c - competition ratio of sesamum and cowpea

Y_{ss}- sole crop yield of sesamum, Y_{sc}- intercrop yield of sesamum

Y_{cc}- sole crop yield of cowpea, Y_{cs}- intercrop yield of cowpea

Z_{sc}- sown proportion of sesamum, Z_{cs}- sown proportion of cowpea

Sesamum equivalent yield (SEY): Sesamum equivalent yield was computed based on the seed yield of the intercropped cowpea and prevailing market price of sesamum and cowpea, based on the crop equivalent yield (Lal and Ray 1976. Verma and Modgal 1983).

$$SEY = Y_{sc} + Y_{cs} \times \left\{\frac{P_c}{P_s}\right\}$$

where,

Y_{sc}- intercrop yield of sesamum, Y_{cs}- intercrop yield of cowpea

P_c- market price of cowpea, P_s- market price of sesamum

Percentage yield difference (PYD): Percentage yield difference was computed (Afe and Atanda 2015).

$$PYD = 100 - \left[\left\{\frac{Y_{SS} - Y_{SC}}{Y_{SS}} + \frac{Y_{CC} - Y_{CS}}{Y_{CC}}\right\}\right] \times \frac{100}{1}$$

where,

Y_{ss}- sole crop of sesamum, Y_{cc}- sole crop of cowpea

Y_{sc}- intercrop yield of sesamum, Y_{cs} - intercrop yield of cowpea

RESULTS AND DISCUSSION

Seed yield: Seed yield of both sesamum and cowpea were significantly influenced by individual and interaction effects (Tables 1, 2 3). The highest seed yield (1193 kg/ha) of sesamum was observed with 75 % RDN (n_2), whereas, the

Table 1. Effect of levels of nitrogen, row ratios and AMF on seed yield of sesamum and cowpea

Treatment	Seed yield (kg/ha)	
	Sesamum	Cowpea
Levels of nitrogen (N)		
n_1 – 100 % recommended dose of nitrogen	947^b	1647^a
n_2 – 75 % recommended dose of nitrogen	1193^a	1292^b
n_3 – 50 % recommended dose of nitrogen	802^c	1170^b
CD (p=0.05)	97.6	257.3
Row ratios (R)		
r_1 – 4:2	953	1355
r_2 – 6:3	1009	1384
CD (p=0.05)	NS	NS
AMF (A)		
a_1 – without AMF	994	1292
a_2 – with AMF	967	1447
CD (p=0.05)	NS	NS

AMF- Arbuscular mycorrhizal fungi; NS – Not significant

Table 2. Effect of N x R, R x A and N x A interactions on seed yield of sesamum and cowpea

Treatment	Seed yield (kg/ha)	
	Sesamum	Cowpea
Levels of nitrogen (N) x Row ratios (R)		
n_1r_1	814^b	1442^b
n_1r_2	1081^a	1852^a
n_2r_1	1216^a	1415^b
n_2r_2	1171^a	1168^b
n_3r_1	829^b	1207^b
n_3r_2	775^b	1132^b
CD (p=0.05)	138.1	363.9
Row ratios (R) x AMF (A)		
r_1a_1	892^c	1220
r_1a_2	1014^{ab}	1489
r_2a_1	1097^a	1364
r_2a_2	921^{bc}	1404
CD (p=0.05)	112.7	NS
Levels of nitrogen (N) x AMF (A)		
n_1a_1	970^{bc}	1602
n_1a_2	924^c	1692
n_2a_1	1311^a	1145
n_2a_2	1076^b	1439
n_3a_1	701^d	1129
n_3a_2	902^c	1210
CD (p=0.05)	137.968	NS

See Table 1 for treatment details

Table 3. Effect of N x R x A interactions on seed yield of sesamum and cowpea

Treatment	Seed yield (kg/ha)	Seed yield (kg/ha)
	Sesamum	Cowpea
Levels of nitrogen (N) x Row ratios (R) x AMF (A)		
$n_1r_1a_1$	729	1378
$n_1r_1a_2$	898	1507
$n_1r_2a_1$	1211	1827
$n_1r_2a_2$	950	1877
$n_2r_1a_1$	1240	1173
$n_2r_1a_2$	1192	1658
$n_2r_2a_1$	1382	1116
$n_2r_2a_2$	959	1221
$n_3r_1a_1$	706	1111
$n_3r_1a_2$	952	1304
$n_3r_2a_1$	696	1148
$n_3r_2a_2$	853	1116
CD (p=0.05)	NS	NS
Sole crop of sesamum without AMF	1138	1369
Sole crop of sesamum with AMF	1218	1649

See Table 1 for treatment details

treatment n_1 (100 % RDN) resulted in highest seed yield (1647 kg/ha) of cowpea. Considering the interaction effects, n_2r_1, r_2a_1, and n_2a_1 observed to have significantly higher seed yield (1216 kg/ha, 1097 kg/ha, and 1076 kg/ha respectively) of sesamum. The highest seed yield (1852 kg/ha) in cowpea was observed with the treatment n_1r_2 (100 % RDN at 6:3 row ratio). The 75 % RDN improved the yield of sesamum instead of growth. The combination of 75 % RDN with 6:3 row ratio, and without AMF application was favourable for increased yield in sesamum. Cowpea, as a high nitrogen requiring crop, it might have also used part of nitrogen that supplied for sesamum under full dose recommendation. The treatment, n_1r_2 (100 % RDN at 6:3 row ratio) proved its significance on seed yield of cowpea.

Land equivalent ratio: Irrespective of the treatments, all the sesamum + cowpea system resulted in LER of >1 indicates the yield advantage of the system, hence cowpea can be regarded as better component crop for sesamum. Among the treatment combinations, 100 % RDN at 6:3 row ratio without AMF ($n_1r_2a_1$) resulted in higher LER (2.40) followed by $n_2r_2a_1$ (2.03) (Table 4). Kotadiya et al (2023) reported the yield advantage of sesamum – pulse intercropping system in terms of LER.

Relative crowding coefficient: The 'K' value for sesamum, cowpea and the intercropping system varied among treatments (Table 4). The higher K value for sesamum (2.92) and cowpea (21.14) observed with $n_2r_1a_2$ and $n_1r_1a_2$ respectively, whereas RCC of the sesamum + cowpea intercropping system was observed to be higher (66.18) with 100 % RDN at 6:3 row ratio without AMF ($n_1r_2a_1$). When comparing to sesamum, cowpea was higher K value. The similar results were reported by Bhatti et al (2006). Aggressivity, RCC and CR revealed superior competitiveness of cowpea over sesamum when compared to other leguminous intercrops tested. This showed that when planted with sesamum, cowpea outperformed all other intercrops in terms of competitiveness by effectively utilizing the available resources.

Aggressivity: Irrespective of the treatment combinations, the aggressivity value (Table 4) of cowpea was positive (+) and that of sesamum negative (-) indicating the dominant behavior of cowpea over sesamum. The treatment, $n_1r_2a_2$ recorded higher (2.40) value of aggressivity for cowpea followed by $n_3r_2a_1$ (2.25) .The findings on aggressivity of cowpea are akin to the results of Bindhu et al (2014) and Bhatti et al (2006). Bhatti et al (2005) reported yield reduction in sesamum due to the luxuriant vegetative development of cowpea compared to other pulse crops.

Competition index: The competition index for all the treatment combinations were observed to lesser than unity (Table 5), indicating yield advantage of the sesamum + cowpea intercropping system. This indicates that, even if

Table 4. Effect of intercropping on land equivalent ratio (LER), relative crowding coefficient (K) and aggressivity (A)

Treatment	LER	Relative crowding coefficient			Aggressivity	
		K_{sc}	K_{cs}	K	A_{sc}	A_{cs}
$n_1r_1a_1$	1.65	0.89	-324.12	-288.85	-1.64	+1.64
$n_1r_1a_2$	1.65	1.40	21.14	29.67	-1.52	+1.52
$n_1r_2a_1$	2.40	-8.29	-7.98	66.18	-2.21	+2.21
$n_1r_2a_2$	1.92	1.77	-16.50	-29.24	-2.40	+2.40
$n_2r_1a_1$	1.95	-6.08	11.97	-72.76	-1.19	+1.19
$n_2r_1a_2$	1.98	2.92	-190.00	-554.80	-1.54	+1.54
$n_2r_2a_1$	2.03	-2.83	-7.74	21.91	-0.34	+0.34
$n_2r_2a_2$	1.53	1.85	5.70	10.55	-0.57	+0.57
$n_3r_1a_1$	1.43	0.82	8.59	7.02	-0.99	+0.99
$n_3r_1a_2$	1.57	1.79	7.55	13.50	-0.80	+0.80
$n_3r_2a_1$	1.45	0.79	10.39	8.19	-2.25	+2.25
$n_3r_2a_2$	1.38	1.17	4.19	4.88	-0.83	+0.83

See Table 1 for treatment details; K_{sc}, A_{sc} and K_{cs}, A_{cs} – relative crowding coefficient and aggressivity of sesamum in combination with cowpea respectively and cowpea in combination with sesamum respectively

Table 5. Effect of intercropping on competition index (CI), competition ratio (CR), sesamum equivalent yield (SEY), percentage yield difference (PYD)

Treatment	CI	Competition ratio		SEY (kg/ha)	PYD (%)
		CR_s	CR_c		
$n_1r_1a_1$	0.05	0.32	3.12	1133	64.68
$n_1r_1a_2$	0.03	0.37	2.71	1389	70.27
$n_1r_2a_1$	0.02	0.53	1.88	1801	139.87
$n_1r_2a_2$	-0.04	0.39	2.56	1617	97.28
$n_2r_1a_1$	-0.01	0.54	1.84	1679	94.65
$n_2r_1a_2$	0.00	0.49	2.04	1753	105.26
$n_2r_2a_1$	-0.06	0.61	1.65	1717	102.96
$n_2r_2a_2$	0.09	0.39	2.54	1286	58.29
$n_3r_1a_1$	0.14	0.31	3.22	1004	43.16
$n_3r_1a_2$	0.07	0.39	2.56	1321	62.70
$n_3r_2a_1$	-0.02	0.31	3.27	1188	45.06
$n_3r_2a_2$	0.11	0.35	2.86	1203	42.59

See Table 1 for treatment details
CR_s – competition ratio of sesamum; CR_c – competition ratio of cowpea

there exists dominance of cowpea over sesamum, over all it provides a favorable environment for higher productivity of the intercropping system. Kumar et al (2021) concluded that, short duration grain legumes with sesamum in an intercropping system could be advantageous, resulting in a synergistic relationship where both crops benefit from shared resources, further enhanced the overall productivity of the system.

Competition ratio: Cowpea recorded higher CR value than sesamum in all treatment combinations (Table 5). The $n_3r_2a_1$ (50 % at 6:3 row ratio without AMF) recorded higher CR for cowpea (3.27) followed by $n_3r_1a_1$ (3.22). The higher CR value indicates more competition between sesamum and cowpea. Superiority of cowpea in the intercropping systems was reported by Bhatti et al (2006).

Sesamum equivalent yield: The $n_1r_2a_1$ (100% RDN at 6:3 row ratio without AMF) resulted in significantly higher (1801 kg/ha) SEY (Table 5) followed by $n_1r_1a_2$ and $n_2r_2a_1$.This could be solely attributed to the higher overall seed yield (Table 3) observed in these treatment combinations. The combined individual and interactive effects of the treatments played a significant role in enhancing the yield attributes of both sesamum and cowpea ultimately leading to a comparatively higher total seed yield for the sesamum + cowpea intercropping system, hence the higher SEY.

Percentage yield difference: Percentage increase in yield was higher (139.87 %) for $n_1r_2a_1$ (100 % RDN at 6:3 row ratio without AMF) followed by $n_2r_1a_2$ and $n_2r_2a_1$. The percentage yield difference was the least (42.59 %) in $n_3r_2a_2$ (50 % RDN at 6:3 row ratio with AMF). The yield reduction of sesamum was compensated by increase in the yield of cowpea. Percentage yield difference can be taken as a parameter to interpret the efficiency of intercropping system as it follows the trend of LER.

CONCLUSION

This study reveals the potential of growing sesamum and cowpea together as an intercropping system, showing improved productivity and biological efficiency. The intercropping system outperforms individual crops in terms of overall productivity and resource use efficiency, regardless of the specific treatment conditions. Among the various treatment combinations, the sesamum + cowpea intercropping system planted at 6:3 row ratio, provided with 100% recommended dose of fertilizers and without AMF application observed to be better.

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