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KR Ganvit
Ph.D. Scholar, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

BB Ramani
Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Dr. SG Savalia
Department of Soil science and Agriculture chemistry, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

JR Joshi
Department of Agronomy, C P College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Dantiwada, Gujarat, India

Corresponding Author:
KR Ganvit
Ph.D. Scholar, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, India

Biological indices of summer sesame based intercropping system

KR Ganvit, BB Ramani, Dr. SG Savalia and JR Joshi

Abstract
A field experiment entitled "Production potential and economics of summer sesame based intercropping system" was carried out under medium black calcareous and slightly alkaline soil during summer seasons of 2021 and 2022 at the Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh. The experiment consisting 10 treatments *viz.,* Sesame sole, Fodder sorghum sole, Fodder pearlmillet sole, Sweet corn sole, Sesame + Fodder sorghum (3:1), Sesame + Fodder sorghum (6:1), Sesame + Fodder pearlmillet (3:1), Sesame + Fodder pearlmillet (6:1), Sesame + Sweet corn (3:1) and Sesame + Sweet corn (6:1) were evaluated in randomized block design with three replications. The productivity of these intercropping systems in terms of sesame equivalent yield was significantly higher (5386 kg/ha) under sole sweet corn and under different intercropping systems intercropping of sesame + sweet corn (3:1) was recorded higher. The biological efficiency of the sesame based intercropping system in terms of LER (1.23), LEC (0.37) and ATER (1.22) were also recorded high under sesame + sweet corn (3:1).

Keywords: Sesame, fodder sorghum, fodder pearlmillet, sweet corn, sesame equivalent yield, land equivalent ratio, land equivalent coefficient and area timr equivalent ratio

Introduction
In many developing countries, the greatest challenge of the twenty-first century is to produce more and more basic necessities like food, fodder, fuel and fiber from the limited available land for an ever-increasing human and animal population. Almost all of the world's food will have to come from land-based agriculture. Land for agriculture is becoming increasingly scarce as it is increasingly used for non-agricultural reasons. In this context, developing novel high-intensity cropping systems, such as intercropping systems involving biotic and abiotic stress-management, soil-building, protein-containing and oil-producing crops, is one of the most essential tactics for increasing agricultural output.

Climate conditions in the country are quite diverse and even minor changes in the weather can have an impact on the region's overall farming system. To combat climate change, policymakers and industry should consider agricultural diversification and intensification. These methods will be especially important for small and marginal farmers who depend on a small plot of land and a single crop for their livelihood (Chourey *et al*., 2018) [8]. In rainfed areas, crop diversity and intensification are used to minimize the risk of crop failure due to drought.

Indian agriculture is interwoven traditionally with cropping and farming systems where crop-production practices compliment dairy production and other entrepreneurship with the farmers aiming to be self-sufficient in the first place, in raising a few crops for home requirement and also to maintain one or two dairy animals. Livestock plays an important role in rural economy of India by providing employment and supplementing family income by contributing about 21% of the total agriculture income of the family (Sharma *et al*., 2009) [23]. The straw, stover and stalks of crops would provide some fodder supplementing the fodder specially raised for the purpose. With the per capita land availability currently falling to 0.11 hectares from 0.40 hectares in 1947 and with increasing demand for food production to meet the human needs, the grass lands and pasture have been dwindling and fodder production is not commensurate with the requirements of the existing cattle population.

Intercropping is an age-old technique in India, specifically in rain-fed areas, that tries to increase total production per unit area while also equally and judiciously utilizing land resources and farming inputs, such as labour (Mohapatra *et al*., 2013) [17]. The main goal of intercropping is to increase total production per unit area of land per unit time by growing many crops in the same field, with the primary goal being improved environmental resource utilization (Khokhar *et al.*, 2004) [13, 14]. In rainfed areas, the intercropping technique is most commonly used as a risk cover against crop failures caused by monsoon vagaries, pest assault and uneven rainfall distribution (Sharma *et al*., 2010) [22].

The most important aspect of a successful intercropping system is crop compatibility. Any intercropping system's effectiveness is contingent on the right selection of crop species that limit competition for light, space, moisture and nutrients (Fukai and Trenbath, 1993) [9]. On the other hand, in intercropping, choosing the right crop species can dramatically enhance overall productivity per unit of area and time (Midmore, 1993) [16]. Yield advantage develops as growth resources such as light, water and nutrients required by the intercrops fluctuate across time and space as a result of variations in competing abilities for growth resources between the crops in features such as rates of canopy development, ultimate canopy size, photosynthetic adaptation of canopies to irradiance conditions and rooting depth (Midmore, 1993; Tsubo *et al*., 2001) [16, 25]. When the intercrop's component species utilize quantitatively different resources or the same resources in various places or at different times, it is known as complementary resource utilization (Tofinga *et al*., 1993) [24].

Intercropping is recommended to be used in many parts of the world for food or fiber production because of its overall high productivity, effective control of pests and diseases, good ecological services and economic profitability. In an intercropping system, there are often two or more crop species are grown in the same field for a certain period of time, even though the crops are not necessarily sown or harvested simultaneously. In practice, most intercropping systems involve only two crops, as the inclusion of more crops results in higher labour costs. Mostly, intercropping is practiced with the aim of maximum plant competition rather than plant competition for maximum crop yield.

Any scheme or plant to increase food and oil production cannot be a total success unless and until an appropriate production-oriented cropping system and production technology are developed and implemented properly. The practice of multi-cropping in the form of intercropping has been a unique asset of tropical and subtropical areas and is becoming popular day by day among small farmers. It has been recognized as a potentially beneficial system to increase crop production per unit time and area, which can provide substantial yield advantages compared to sole cropping. These advantages may be especially important because they are achieved not by means of costly inputs, but by the simple expedient of growing crops together (Willey, 1979) [26]. Spatial arrangement in intercropping is one of the most important factors for higher yield. The negative point of intercropping of cultures would be the higher competition for water, light and nutrients that tends to diminish the profitability of each separate crop to a higher or lower degree. However, according to Asten *et al*. (2011) [5], intercropping benefits may increase through the correct use and management of the soil, plant density and planting configuration. Intercropping may be a potential system in crop production providing insurance against biotic and abiotic stresses in a rainfed upland ecosystem.

Sesame (*Sesamum indicum* L.) belongs to the family pedaliaceae, is an important oilseed crop being cultivated in the tropics and temperate zones of the world (Biabani and Pakniyat, 2008) [7]. It is a potentially high yielding oilseed crop widely grown in India, Myanmar, Sudan, Tanzania and China. It is one of the most ancient oilseed crops, having been grown for over 5000 years. Sesame is also popularly known as sesamum, til, simsim and gergelim etc. It is generally cultivated throughout the year *i.e*., during *kharif*, semi-*rabi* and summer as a sole crop as well as mixed or intercrop. It is one of the most preferred oilseed crops under rainfed conditions, even with a low yield level, because of its higher price and good quality oil. It is very sensitive to biotic and abiotic stresses. As a result, uncertainty prevails with sesame cultivation.

Sesame is known as "The Queen of the Oilseed Crops" due to the excellent quality of its oil, flavor, taste and softness. It is considered to have both nutritional and medicinal values. Sesame seeds are used in numerous cuisines all over the world. Sesame is a rich source of oil (46-52%) and protein (18-20%). Sesame seeds are also rich in calcium, phosphorus, potassium and vitamin E. Its high quality and staple oil have a high index of sesamin, sesamol and sesamolin antioxidants as well as monounsaturated and polyunsaturated fatty acids (Rangkadilok *et al.*, 2010) [21]. The presence of antioxidants makes the sesame oil highly preservable as a result of which it does not get rancid (Ahuja *et al*., 1971) [2].

Commercially, sesame oil is used directly in pharmaceutical industries in plastering and manufacturing of soaps. Moreover, it is also used for preparation of hair oil, body lotion and fixative in perfume industries in cosmetics and adulterant with olive oil and Vanaspati ghee. Sesame being a short duration crop, has the potential to enhance cropping systems intensification and diversification (Oyeogbe *et al*., 2015) [18]. The fatty acid composition of sesame reveals that linoleic, oleic, palmitic and stearic acids are its major constituents. The oil is highly resistant to oxidative rancidity and is characterized for its stability and quality. Because of its excellent quality characters, sesame oil is also sometimes referred to as “poor man’s substitute for ghee”. Sesame cake obtained as a by-product of oil milling industry is rich in protein, carbohydrates, vitamin (Niacin) and minerals (Ca & P). It is eaten mixed with sugar by poor peoples and sometimes also added to bread to improve palatability and nutritive value. Sesame cake is also a valuable nutritious feed for cattle especially for milch animals and is ingredient of poultry feed because of its high methionine content. The cake contains 6.0-6.2% N, 2.0-2.2% P and 1.0-1.2% K and can also be used as manure.

India ranks second in area (18.94%) next to Sudan, first in production (14.83%) and higher in export (17.56%) of sesame (Anon., 2020a) [3]. India accounts for the production of 6.58 lakh tonnes from 16.23 lakh ha area with 405 kg/ha productivity of sesame during 2019-20. While, Gujarat occupies about 1.66 lakh ha area, 1.08 lakh tonnes of production and 649 kg/ha productivity of sesame during 2019-20 (Anon., 2020b) [4]. The major sesame growing districts in Gujarat state are Amreli, Bhavnagar, Jamnagar, Rajkot, Kutchh, Junagadh and Surendranagar. The area and production of sesame are higher in *kharif* season while, productivity is higher in summer season. Sesame is grown in all seasons of the year and being a short duration crop, fits well into the various cropping systems. The crop is generally cultivated as sole or mixed crop during *kharif*, semi-*rabi* and now a days profitably grown in summer season in all districts of Gujarat state except Dang and Valsad.

Materials and Methods
The field experiment was conducted in summer seasons of year 2021 and 2022 at Instructional farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural university, Junagadh. The experiment was conducted on medium black clayey textured soil, which was medium in organic carbon (0.69 and 0.65% in 2021 and 2022, respectively), slightly alkaline in reaction with pH (8.01 and 7.98 in 2021 and 2022, respectively) and EC (0.48 and 0.53 ds/m in 2021 and 2022, respectively). The soil was medium in available nitrogen (251.30 and 257.18 kg/ha in 2021 and 2022, respectively), medium in available phosphorus (38.14 and 36.57 kg/ha in 2021 and 2022, respectively) and medium in available potash (268.20 and 274 kg/ha in 2021 and 2022, respectively).

The mean maximum temperature of 40.9 °C was recorded in 2nd week of April-2021 and ranged upto 31.1 °C in 1st week of February-2021. The mean minimum temperature of 10.9 °C was recorded in 1st week of February -2021 and ranged upto 28.0 °C in 2nd week of June-2021. The range of average relative humidity, wind speed, bright sun shine hours and daily evaporation was 36.5-76.0%, 3.4-12.6 km/hr, 1.4-10.3 hr and 4.6-9.3 mm, respectively during the year 2021. Rainfall of 47.8 mm was received during 3rd week of May-2021. However, it was not affected crop adversely.

While in year 2022, the mean maximum temperature of 42.8 °C was recorded in 4th week of April-2022 and ranged upto 29.0 °C in 1st week of February-2022. The mean minimum temperature of 12.7 °C was recorded in 2nd week of February-2022 and ranged upto 26.6 °C in 3rd week of June-2022. The range of average relative humidity, wind speed, bright sun shine hours and daily evaporation was 33.5-74.5%, 4.1-14.2 km/hr, 1.8-11.0 hr and 4.8-10.8 mm, respectively during the year 2022.

Ten treatment comprising intercropping system viz, Sesame sole, Fodder sorghum sole, Fodder pearlmillet sole, Sweet corn sole, Sesame + Fodder sorghum (3:1), Sesame + Fodder sorghum (6:1), Sesame + Fodder pearlmillet (3:1), Sesame + Fodder pearlmillet (6:1), Sesame + Sweet corn (3:1) and Sesame + Sweet corn (6:1) were evaluated in randomized block design with three replications.

The entire recommended doses of fertilizer for sesame, fodder sorghum, fodder pearlmillet and sweet corn as per sole and intercrops on the basis of area occupied were applied at the time of sowing in the furrows and covered with soil. Entire doses of nitrogen, phosphorus was applied in previously opened furrows just before sowing as basal application in form of Urea and Diammonium Phosphate (DAP).

The biological indices intercropping system were determined in terms of the sesame equivalent yield (SEY), land equivalent ratio (LER), land equivalent coefficient (LEC) and area time equivalent ratio (ATER). All the data were subjected to statistical analysis by adopting appropriate analysis of variance. Wherever the F values found significant at 5% level of probability, the critical difference (CD) values were computed for making comparison among the treatment means as described by Panse and Sukhatme (1985) [20].

Sesame Equivalent Yield (CEY)
The sesame equivalent yield of intercropping systems was calculated by considering the yield of component crops and prevailing market price of both main crop and intercrops. The SEY of intercropping systems was calculated by using the following formula.

$$\text{SEY (kg/ha)} = \text{Yield of main crop (kg/ha)} + \frac{\text{Yield of intercrop (kg/ha)} \times \text{Market price of intercrop (₹/kg)}}{\text{Market price of main crop (₹/kg)}}$$

In this experiment, sesame is main crop hence Sesame Equivalent yield (SEY) was calculated by using the above formula.

Land Equivalent Ratio (LER)
Land equivalent ratio is defined as the "relative land area under sole crop that is required to produce the yield obtained in intercropping system". LER was used criterion for measuring efficiency of intercropping advantage using the resources of environment compared with monocropping. When the value of LER is >1, intercropping favours the growth and yield of the species. By contrast, when LER <1, intercropping negatively affects the growth and yield of the plants grown in mixtures. The LER was worked out by the following formula suggested by Mead and Willey (1980) [15].

$$\text{LER} = \text{LA} + \text{LB} = \frac{\text{YA}}{\text{SA}} + \frac{\text{YB}}{\text{SB}}$$

Where,
LA and LB are the LER for individual crops.
YA and YB are the individual crop yield in intercropping.
SA and SB are their sole crop yields.

Land Equivalent Coefficient (LEC)
Land equivalent coefficient (LEC) was calculated by using the following formula suggested by Adetiloye *et al.* (1983) [1].

$$\text{LEC} = \text{LA} \times \text{LB}$$

Where,
LA = LER of main crop
LB = LER of intercrop

Area Time Equivalent Ratio (ATER)
Area time equivalent ratio (ATER) provides more realistic comparison of the yield advantage of intercropping over monocropping in terms of time taken by component crops in the intercropping systems. ATER was calculated by using the following formula suggested by Hiebsch and McCollum (1987).

$$\text{ATER} = \frac{(\text{LA} \times \text{TA}) + (\text{LB} \times \text{TB})}{\text{T}}$$

Where,
LA and LB = Partial LER of crop A and B
TA and TB = Duration (days) of crop A and B
T = Duration (days) of the intercropping system

Results and Discussion
The results indicated that various intercropping systems exhibited their significant influence on sesame equivalent yield (Table 1). Significantly the highest sesame equivalent yield was obtained under intercropping of sesame + sweet corn (3:1). This might be due to better utilization of different resources particularly under extreme high temperature of summer season comparatively more income from cob and

high fodder yield in this intercropping system. However, significantly lower sesame equivalent yield was obtained under sole pearlmillet.

Land equivalent ratio of intercropping systems were computed and presented in Table 1. Significantly the highest value of mean land equivalent ratio was obtained under intercropping of sesame + sweet corn (3:1) over other intercropping systems. This result indicated that 23% greater area would be required by a sole cropping system to recover the yield of intercropping system. Sesame + sweet corn intercropping systems had higher LER than 1 except other intercropping system, which shows advantage of intercropping sesame with sweet corn. The advantage accrued from intercropping systems, as evident from competitive functions, is due to better utilization of all resources under mixtures.

Land equivalent coefficient was significantly influenced by different intercropping systems (Table 2). Among the various intercropping systems, significantly the highest value of land equivalent coefficient noted under intercropping of sesame + sweet corn (3:1) during the both years and in pooled results.

Area time equivalent ratio provides more a realistic comparison of the yield advantage of intercropping over that of sole cropping than LER as it considers variation in time taken by the component crops of different intercropping systems. Among the intercropping systems, significantly the highest value of area time equivalent ratio was recorded under intercropping of sesame + sweet corn (3:1) during both the years and in pooled results (Table 2). Area time equivalent ratio was greater than one under intercropping of sesame + sweet corn (3:1) intercropping systems advantage over rest of intercropping systems. In contrast, area time equivalent ratio was less than one, which indicated poor utility of all resources under rest of intercropping systems.

These findings are in vicinity of those reported by Khokhar *et al*. (2004) [13, 14], Padhi and Panigrahi (2006) [19], Ijoyah *et al*. (2014) [12], Ijoyah *et al*. (2015) [11] and Bhagat *et al*. (2022) [6].

Table 1: Sesame equivalent yield and Land equivalent ratio as influenced by sesame based intercropping systems

Treatment			Sesame equivalent yield (kg/ha)			Land equivalent ratio		
			2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_1	:	Sesame sole	1242	1260	1251	1.00	1.00	1.00
T_2	:	Fodder sorghum sole	1274	1134	1204	1.00	1.00	1.00
T_3	:	Fodder pearlmillet sole	1151	1027	1089	1.00	1.00	1.00
T_4	:	Sweet corn sole	5633	5139	5386	1.00	1.00	1.00
T_5	:	Sesame + Fodder sorghum (3:1)	1245	1232	1239	1.00	1.01	1.01
T_6	:	Sesame + Fodder sorghum (6:1)	1164	1160	1162	0.93	0.94	0.93
T_7	:	Sesame + Fodder pearlmillet (3:1)	1220	1207	1214	1.00	1.01	1.01
T_8	:	Sesame + Fodder pearlmillet (6:1)	1173	1177	1175	0.96	0.97	0.96
T_9	:	Sesame + Sweet corn (3:1)	3952	3716	3834	1.22	1.23	1.23
T_{10}	:	Sesame + Sweet corn (6:1)	2754	2499	2627	1.08	1.10	1.09
		S.Em.±	103.72	95.62	70.54	0.03	0.03	0.02
		C.D. at 5%	308	284	202	0.08	0.08	0.06
		C.V. %	8.63	8.47	8.56	4.74	4.55	4.64
		Year						
		S.Em.±			31.54			0.01
		C.D. at 5%			NS			NS
		Y x T						
		S.Em.±			99.75			0.03
		C.D. at 5%			NS			NS

Table 2: Land equivalent coefficient and Area time equivalent ratio under sesame based intercropping systems

Treatment			Land equivalent coefficient			Area time equivalent ratio		
			2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_1	:	Sesame sole	1.00	1.00	1.00	1.00	1.00	1.00
T_2	:	Fodder sorghum sole	1.00	1.00	1.00	1.00	1.00	1.00
T_3	:	Fodder pearlmillet sole	1.00	1.00	1.00	1.00	1.00	1.00
T_4	:	Sweet corn sole	1.00	1.00	1.00	1.00	1.00	1.00
T_5	:	Sesame + Fodder sorghum (3:1)	0.19	0.20	0.20	1.00	1.01	1.00
T_6	:	Sesame + Fodder sorghum (6:1)	0.12	0.12	0.12	0.93	0.93	0.93
T_7	:	Sesame + Fodder pearlmillet (3:1)	0.21	0.21	0.21	1.00	1.01	1.01
T_8	:	Sesame + Fodder pearlmillet (6:1)	0.15	0.15	0.15	0.96	0.97	0.96
T_9	:	Sesame + Sweet corn (3:1)	0.37	0.38	0.37	1.22	1.23	1.22
T_{10}	:	Sesame + Sweet corn (6:1)	0.24	0.25	0.25	1.08	1.10	1.09
		S.Em.±	0.01	0.01	0.01	0.03	0.03	0.02
		C.D. at 5%	0.02	0.02	0.02	0.08	0.08	0.06
		C.V. %	2.72	2.70	2.71	4.75	4.56	4.65
		Year						
		S.Em.±			0.00			0.01
		C.D. at 5%			NS			NS
		Y x T						
		S.Em.±			0.01			0.03
		C.D. at 5%			NS			NS

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