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The Effect of Diverse Intercropping System on Growth Indices, Yield and Profitability of Indian Mustard (*Brassica juncea* L.): Variety Azad Mahak

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Intercropping enhances crop yield and quality by growing different crop species together on the same piece of land in distinct row combinations. Hence, a field experiment was conducted to study the suitable combination of mustard based intercropping with different crops at students' instructional farm, C. S. Azad University of Agriculture & Technology, Kanpur (U.P.) during Rabi season 2021-22. The experiment was laid out in Randomized Block Design with nine treatment combinations viz., T1 Sole Mustard, T2 Mustard: Chickpea (1:1), T3 Mustard: Chickpea (2:1), T4 Mustard: Lentil (1:1), T5 Mustard: Lentil (2:1), T6 Mustard: Linseed (1:1), T7 Mustard: Linseed (2:1), T8 Mustard: Field Pea (1:1) and T9 Mustard: Field Pea (2:1) with replicated thrice. The result revealed that growth attributes in the intercropping system were most notably observed in sole Mustard, with the Mustard + Lentil (1:1) system following closely. The Mustard + Lentil (1:1) intercropping system yielded a significantly higher mustard equivalent yield (2.77 t ha^{-1}). Notably, the greatest net returns were obtained from sole Mustard cultivation (INR 151,045.50 ha-1), though the Mustard + Lentil (1:1) system also produced substantial returns (INR 144,001.00 ha^{-1}). Furthermore, the benefit-cost ratio was highest for sole Mustard (5.05), with the Mustard + Lentil (1:1) system (4.82). In conclusion, these results support the superior productivity and profitability of sole Mustard cultivation, closely followed by the Mustard + Lentil (1:1) intercropping system.

Keywords: Intercropping; mustard; chickpea; pea; lentil; linseed; growth; yield; profit.

1. INTRODUCTION

Current agriculture is confronted with formidable problems of stagnating production due to decline in factor productivity, degrading soil health, inefficiency of current production practices and scarcity of resources, high cost of cultivation and low returns to the farmers as ill effects of green revolution which concentrates on maximum output but overlooks input efficiency [1]. On the other hand per capita land availability is going to decrease, thus this limitation imposing more pressure to produce more food, feed, fiber, fuel and fodder per unit area to meet basic needs of growing population [2]. The problem is likely to be further execrated by the climate change which poses new threats for sustainability of major cropping systems. The horizontal increase in crop production is not possible, but the only way to increase crop productivity on per unit area basis is possible through intercropping [3]. Thus to meet out the challenges imposed by overuse of natural resources and to sustain productivity level improved crop management through inclusion of legume crops in crop rotations and intercropping of legumes with cereals have many potential benefits as compared to sole cropping systems [4].

Intercropping is an effective approach for boosting the production and quality productivity of crop through practices of cultivating two or more economic dissimilar crop species in distinct row combinations simultaneously on the same piece of land [5]. This practice increased diversity in the cropping system [6]. Intercropping is defined as growing of two or more dissimilar crops simultaneously on the same piece of land in a distinct row arrangement using one crop as a base crop to which rows of an additional component crop is added. Intercropping is an age old practice in India, especially under rainfed conditions, which aims to increase total productivity per unit area and to equitably and judiciously utilize land resources and farming inputs including labour [7]. Development of feasible and economically viable intercropping systems largely depends on selection of compatible crops and adoption of proper planting geometry [8]. Thus, the objective of intercropping is now more towards augmenting the total productivity per unit area of the land per unit time by growing more than one crop in the same field, the prime objective being better utilization of environmental resources [9]. As with any cropping system, there are many advantages and disadvantages of intercropping. Although research is still on going, there is strong evidence that intercropping can substantially increase the yield from a given area of land. As well, intercrops may require lower levels of costly inputs through increased resource-use efficiency. One of the most important of intercrops is the increase in yield and sustainability provided by the presence of another crop that may compensate for yield losses in the other crop due to adverse climatic conditions [10]. The traditional practice of intercropping gained popularity in recent years with suitable changes incorporated in planting pattern. Basically intercropping system helps in reducing risk from epidemic of insect and disease, and overcoming the effect of unfavourable environmental conditions in agro-climatologically less stable regions along with better utilization of solar radiation and inputs like fertilizer and water compared to sole cropping system [11]. Diversification of cropping systems is necessary to get higher yield and returns to maintain soil health, preserve the environment and meet the daily requirement of food and feed for human and animals [12]. Growing of mustard along with various crops like Lentil, chickpea, Pea and Linseed as intercrop in a regular practice. If appropriate row ratio of Mustard with oilseeds like Linseed as well as legumes like lentil, pea, chickpea for a specific area is adopted the farmers may use the available resources efficiently and effectively. India is one of the leading oilseed growing countries in the world and third largest vegetable oil economy next only to USA and China [13]. The ranking of oilseeds next after food grains in terms of area and production. Currently, India accounts for approximately 13% of the world's oilseed area, 7% production and 10% edible oilseed consumption. In India, over 80% requirement of vegetable oil and fats are derived from following oilseed crops viz., groundnut, rapeseed-mustard, soybean, sunflower, niger, sesame, safflower, linseed and castor [14]. Oilseeds are raised mostly under rainfed condition and important for the livelihood of small and marginal farmers in arid and semi-arid areas of the country.

Mustard (*Brassica junecia* L.) ranks second (28%) after soyabean (36%) among oilseed crops in India grown for edible oil, used in cooking and frying [15]. Mustard also known as oilseed brassicas has been successfully intercropped with various pulses and oilseeds in the various agro ecological zones in India [16]. It is also grown in certain tropical and sub-tropical regions in winter season crop. It can tolerate moderate salinity reasonably well but a soil having neutral pH is ideal for their proper growth and development. Its oil cake is used as the cattle feed and manure, green foliage as fodder for domestic animals and young plants as green vegetable as they supply enough sulphur in the diet [17]. Linseed (*Linum usitatissimum* L.), also known as flax, is a significant oilseed crop. It's an old world crop likely first cultivated in southern Asia and the Mediterranean region [18]. It is an important *Rabi* season crop, often grown in rainfed conditions and used for intercropping. Linseed's high linolenic acid content (35-66%) makes its oil valuable for products like paints, inks, and varnishes [19].

Pulse crops play an important role in agriculture being rich in proteins, carbohydrate, mineral, vitamins and crude fiber constitute major component of vast majority of vegetarian people of the country [20]. Besides these, they have unique property of maintaining and restoring soil fertility through biological nitrogen fixation (BNF) as well as conserving and improving physical properties of soil by virtue of their deep root system and leaf fall. Chickpea (*Cicer arietinum* L.) grown in sole as well as in mixed stands because of their diverse morphology, growth rhythm and similar climatic requirements [21]. Chickpea is a cool-season legume crop, sown as a winter crop in the tropics or as a spring or summer crop in temperate regions. On global basis, chickpea is the third most important pulse after dry bean and dry peas but in India it is the highest cultivated crop with 40% area among all pulses. India is the premier chickpea growing country accounting 77% of the total area and production of the world. Field pea (*Pisum sativum* L.), is one of the most important pulse crops of the world cultivated over an area of 6.5 million ha with the production of about 10.2 million tonnes. The mature pea is highly nutritive and containing high proportion of digestible protein (18-35%), starch (20-50%), sugars (4-10%), fat (0.6-1.5%), cellulose (2-10%), minerals (4%) along with minerals like Ca, Fe, P and vitamins Vit-A, C, B2, B1 (Singh et al., 2014). The pea plant can also be utilized as a common forage legume (hay, pasture and silage) whereas semi-arid areas field pea is used for seed and green manure. These qualities make field pea one of the best feeds for animals and almost indispensable for efficient, economical livestock feeding. Tender seeds are used in soups. Canned, frozen and dehydrated peas are commonly used during off season. The seeds are used as vegetable or pulse. Lentil is mainly grown in India, Canada, Turkey, USA, Syria and Australia. India has a distinction of being world’s largest producer of pulses [22]. Lentil thrives well in sub-marginal lands with low inputs under water- limited conditions. Lentil is known as poor man’s meat. Nutritionally lentil seeds are valued for their high protein content (as much as 30%) and good source of vitamins and other important minerals (K, P, Fe, Mg, Zn), low in fat and cholesterol free [23]. Lentil seeds contain about 25-27% crude protein, 59% carbohydrates, 0.5% fat, 2.1% minerals and significant amount of vitamins. For obtaining higher return per unit land area intercropping appears to be one of the important aspect. Taking into consideration the above facts, it has become imperative to find out the suitable crops and optimum row ratio for higher productivity under intercropping systems. The objectives are to determine compatible intercrops and row ratios for mustard, identify suitable pulses for intercropping, analyse the impact of intercrops on mustard's competition, and assess the economic viability of various treatments.

2. MATERIALS AND METHODS

2.1 Experimental Site

A field experiment was conducted at Chandra Shekhar Azad University of Agriculture and Technology in Kanpur, Uttar Pradesh (UP) India. It is situated in the central region of Uttar Pradesh, within North India's sub-tropical semi-arid tract. Its geographic coordinates are approximately 26° 29' 35" North latitude and 80° 18' 25" East longitude, with an elevation of around 125.9 meters above mean sea level in the Gangetic plain. Kanpur lies in the central plain zone of Uttar Pradesh, on the right bank of the Ganga River, and falls within the upper Indo-Gangetic plain zone of India.

2.2 Climatic Conditions

The weather data for the 2021-22 *Rabi* season was sourced from the Agro-meteorological Observatory within the department of Agronomy, CSAUA&T Kanpur. Climate refers to the collective weather conditions experienced in a particular region over larger areas such as zones, states, countries, and continents, and longer durations such as months, seasons, and years. This zone has a semi-arid climate with fertile alluvial soil. Annual rainfall is around 937 mm, mainly from mid-June to September. Winters are cooler; with temperatures ranging from 2°C to 3°C with occasional rain and frost occur from late December to mid-January. In contrast, May and June experience high temperatures, often reaching 44°C to 47°C or even higher. Relative humidity is consistently 80-90% from July to March, gradually decreasing to 40-50% by April's end and staying at 60% up to June.

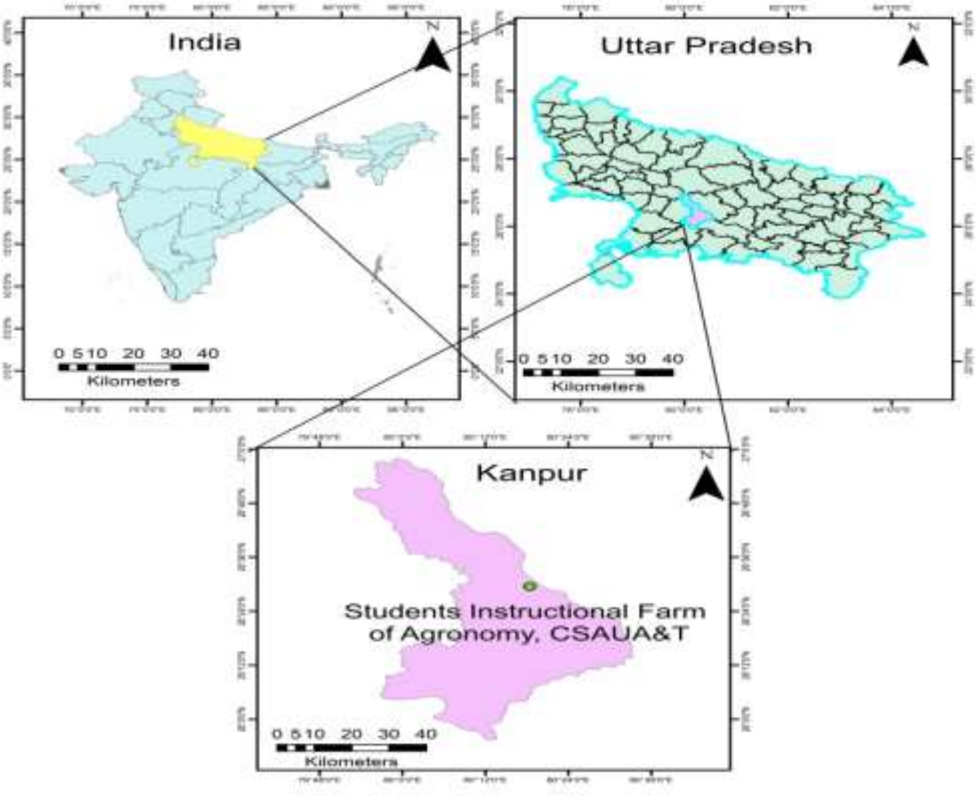

Fig. 1. Location map of the study area

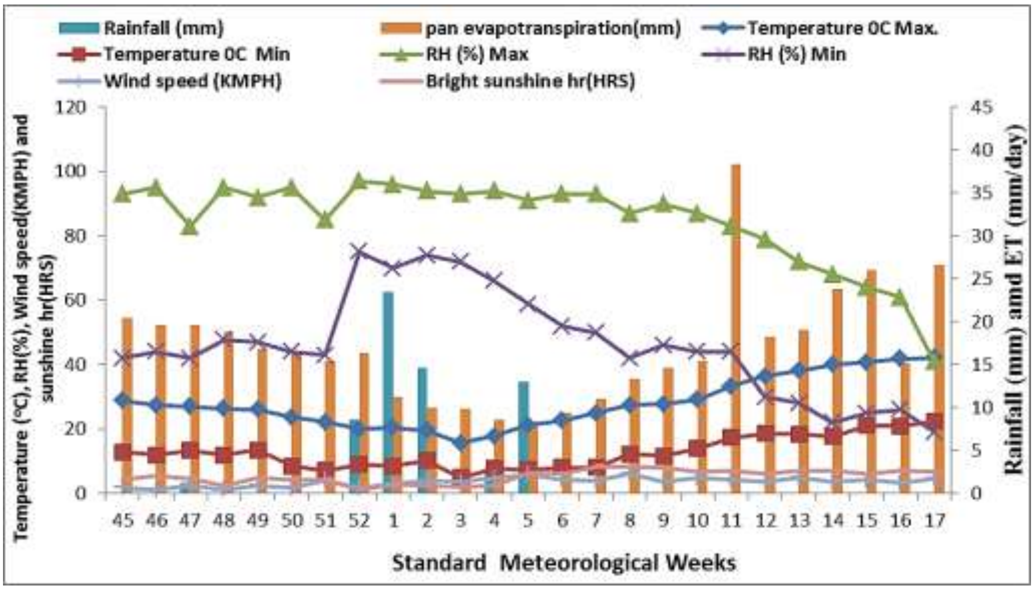

Fig. 2. Details of weather data during crop season (2021-22)

2.3 Soil Characteristics

Soil properties play a crucial role in influencing plant growth and, consequently, the ultimate yield. The experimental field soil is classified as sandy clay loam, with the following specific measurements: pH (7.30), EC (0.33 dsm^{-1}), Organic Carbon (0.43%), available nitrogen (215kg ha^{-1}), P_2O_5 (16.5 kg ha^{-1}), K_2O (147. kg ha^{-1}) and S (10ppm).

2.4 Experimental Details

The experiment was carried out in a Randomized block Design with three replications. The experiment comprised nine treatments combinations *viz*., T_1 Sole Mustard, T_2 Mustard: Chickpea (1:1), T_3 Mustard: Chickpea (2:1), T_4 Mustard: Lentil (1:1), T_5 Mustard: Lentil (2:1), T_6 Mustard: Linseed (1:1), T_7 Mustard: Linseed (2:1), T_8 Mustard: Field Pea (1:1), T_9 Mustard: Field Pea (2:1). The size of each plot was (18 m^2), 5.0 m long and 3.6 m width.

2.5 Crop Varieties

2.5.1 Azad mahak (Mustard)

It was released by Chandra Shekhar Azad University of Agriculture & Technology (CSAUA&T), Kanpur (U.P.). It takes 120-125 days to mature in *Rabi* season. It is suitable for growing in whole Uttar Pradesh. Oil content in this variety is 41.6%-42.1% and yield potential of this variety is 8.82q ha^{-1}.

2.5.2 Uma (linseed)

It was released by CSAUA&T, Kanpur (U.P.) in the year 2017. The yield potential of this variety is 37.68q ha^{-1}. It is suitable for growing in Uttar Pradesh. It tolerant to wilt, rust and alternaria blight disease.

2.5.3 Avrodhi (chickpea)

It was released by CSAUA&T; Kanpur (U.P.).This variety takes 150-155 days to mature in *Rabi* season. This is a medium tall; erect type variety and brown colour grains. This variety is resistant to wilt disease and yield potential is 25-30 q ha^{-1}.

2.5.4 KL-320 (Lentil)

It was released by CSAUA&T, Kanpur (U.P.). These varieties suitable for U.P. timely sown, grain are medium bold, yield potential 15-18 q ha^{-1}.

2.5.5 Sapna (Field Pea)

It was released by CSAUA&T, Kanpur (U.P.). This variety suitable for Uttar Pradesh This variety takes 120-130 days to mature in *Rabi* season, yield potential 25-30 q ha^{-1}.

2.6 Agronomical Practices Adopted

The experimental field preparation began after the *kharif* crop harvest, with pre-sowing irrigation for seed germination. Ploughing involved one round with a disc plough followed by two rounds with a tractor-drawn cultivator, each followed by planking to firm and level the soil. Fertilizers were applied according to recommended doses for each crop. Sowing occurred on October 28, 2021, with definite row ratios and plant spacing. Intercropping was in replacement series, maintaining optimum plant population. Irrigation was provided at branching and pod-filling stages, with manual weeding and disease control using Matco (metalaxyl 8% + mancozeb 64%) @ 1.5 kg ha^{-1}. Harvesting was done manually when pods/siliqua turned yellowish brown and moisture content was around 38%. Harvested plants from each net plot were bundled, sun-dried, and brought to the threshing floor. Each net plot's produce was individually weighed before threshing. Threshing was done using wooden sticks, and the seed weight was carefully recorded. Stover yield was calculated by subtracting seed weight from the total biological yield. Cleaned grain weight was measured with a physical balance. Mustard Stover yields were determined by subtracting grain yield from the total biological yield.

2.7 Observations Recorded

To ensure cost-effective precision, a systematic sampling approach was employed. Specifically, data were collected from five tagged plants within each plot. Various parameters related to mustard, such as plant population, height, number of branches, fresh and dry weight, grain yield, gross and net income, and B:C ratio, were recorded on a per-plot basis.

Gross income: It refers to the total revenue generated from the sale of agricultural products, crops, or livestock before deducting any production costs or expenses. It represents the overall income generated by the agricultural activity. Gross return is an essential metric for farmers and agricultural businesses as it helps them understand the total value of their agricultural production.

Gross income = Total Revenue from Agricultural Sales

Where,
Total revenue = All the income generated from selling agricultural products, such as crops grain and straw and other related products.

Net income: It often referred to as profit, is the income left over after subtracting all expenses and costs from the gross income. It reflects the actual profit earned from agricultural activity, accounting for both the revenue and the various costs incurred, such as operating expenses, inputs, and other overheads. Monetary value gained after compensating the spent money can be said as net income.

Net income = Gross return - Cost of cultivation

Benefit: Cost Ratio: It is an indicator that attempts to summarize the overall value for money of cultivation. It is the ratio of benefit or net income, expressed in monetary value, relative to the cost of cultivation, also expressed in monetary value. It was calculated by dividing the gross income of a treatment plot to the cost of that particular treatment.

B: C Ratio > 1, Mustard farming is economically feasible
B: C Ratio < 1, Mustard farming is not economically feasible
B: C Ratio = 1, Mustard farming is in Break Even Point (BEP)

$$Benefit\ cost\ ratio\ = \frac{Benefit\ cost\ ratio}{Benefit\ cost\ ratio} \times 100$$

Mustard equivalent yield (MEY): Mustard equivalent yield was calculated in terms of Mustard yield for all the intercropping treatments on the basis of Minimum support price (INR/q) for *Rabi* 2021-22. It was calculated using formula as;

$$MEY = \frac{grain\ yield\ intercrop\ \left(\frac{t}{ha}\right) x\ price\ of\ intercrop\ \left(\frac{INR}{t}\right)}{Price\ of\ mustard\ \left(\frac{INR}{t}\right)} + Grain\ yield\ of\ Mustard\ (t/ha)$$

The collected data were then subjected to appropriate statistical analysis using the method outlined by Gomez and Gomez [24] to assess potential significant differences among treatment means. The Least Significant Difference (LSD) test was applied to compare treatment means at a 5% significance level.

3. RESULT AND DISCUSSION

3.1 Plant Population

The population was remained unaffected on all the stages at 30, 60, 90 DAS and at harvest of all crops in all the treatments. However plant population does not show any significant effect due to different intercrops. Major factors affecting crop populations include climate, soil moisture, seed quality, cultural practices, environmental stresses, insect pests and diseases. Plant populations have a profound impact on various growth parameters of mustard, even when growing conditions are optimal. This influence makes it a significant factor in determining the extent of competition among plants. The seed yield per plant tends to rise as plants receive more light and other environmental resources. Stand density plays a pivotal role in shaping plant architecture, altering growth and developmental patterns, and affecting carbohydrate production. At lower densities, many improved mustard varieties struggle to effectively branches, often reduces seeds per siliqua or plant, siliquae per plant. An increase in plant density beyond the optimum level leads to reduced mustard yield primarily due to a decrease in the harvest index and an increase in stem lodging. This situation reflects intense competition among plants for incident photosynthetic photon flux density, soil nutrients, and water. Consequently, the availability of carbon and nitrogen becomes limited, resulting in more barren plants, fewer seeds per siliqua or plant, siliquae per plant and smaller seed sizes.

3.2 Plant height

Plant height in mustard varied significantly at 30, 60, 90 DAS, and at harvest. The maximum plant height recorded in sole mustard (T1) at all stages of growth followed by Mustard + Lentil (1:1) at all stages of growth and minimum where mustard was planted with pea both 1:1, 2:1 ratio at all stages of growth. This variation is directly linked to the competition among plants for nutrients, moisture, air, and light, which plays a pivotal role in determining growth, development and ultimately crop yield. The plant height of mustard in intercrop where chickpea, lentil were statistically at par during 60, 90 DAS as well as at harvest stage except the treatment where mustard was intercropped with pea which was lowest at all stages of all stages of crop growth. These findings align with the results reported by Patra et al. [25] where mustard height was highest in sole planting [26]. Intercropping had a significant impact on plant height at 30 DAS, while at 60, 90 DAS, and at harvest, it also showed significant effects. Plant height was highest when mustard was intercropped in a 1:1 ratio compared to a 2:1 ratio with the intercrop in all other intercropping scenarios. These results are in accordance with the findings of Singh et al. [27] and Malik et al. [28].

3.3 Number of Primary Branches

Number of primary branches per plant of mustard recorded significant result at 30, 60 DAS whereas, 90 DAS and at harvest recorded non-significant. The number of primary branches/plant at 60 & 90 DAS among the different row ratios of intercrops showed that T1 recorded maximum followed by T4, T5 and T2 all these were statistically at par but superior with T3, T6, T7, T8 whereas, minimum in T9. In intercrop number of primary branches per plant was significantly varied at 30, 60, 90 DAS as well as at harvest stage. The maximum number of branches per plant in mustard was recorded in sole mustard, which was significantly higher than all intercropping treatments.

3.4 Number of Secondary Branches

The number of secondary branches per plant of mustard show significant result at all stage 60, 90 DAS and at harvest. The maximum secondary branches recorded with sole mustard crop followed by intercrop combination of T4, T5, T2 and T3 all there were statistically at par but superior over all other intercrop combination, whereas minimum branches recorded with the combination where pea was intercrop with the mustard during 60, 90 DAS as well as at harvest stages.

3.5 Fresh and Dry Weight

Fresh and dry weight per plant of mustard was recorded significant result at all stage viz. 30, 60, 90 DAS and at harvest. Maximum fresh and dry weight per plant of mustard recorded significantly in T1 (sole mustard). Sole mustard accumulated higher dry matter at all the stages of crop growth and also had higher grain yield as compared to all other planting patterns. Lesser dry matter accumulation in intercropping system was due to competing ability of intercrops with mustard. Similar variation in dry matter accumulation among different planting patterns has also been reported by Tahir et al. 2003. In case of intercrops dry weight per plant recorded significant at 30 DAS whereas, 60, 90 DAS and at harvest stage recorded non-significant result. Similar findings reported by Mishra et al. [29].

Table 1. Effect of intercropping system on plant population and height of Mustard

Treatment Combinations	**Plant population (running meter)**				**Plant height (cm)**			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**90 DAS**	**At harvest**
T1 Sole mustard	8.67	8.67	8.67	8.67	24.90	152.50	188.83	196.66
T2 Mustard + Chickpea (1:1)	8.67	8.67	8.33	8.33	24.40	143.20	173.66	184.25
T3 Mustard + Chickpea (2:1)	8.67	8.67	8.67	8.33	24.00	142.30	171.83	183.50
T4 Mustard + Lentil (1:1)	8.67	8.67	8.67	8.67	24.50	150.00	185.25	189.66
T5 Mustard + Lentil (2:1)	8.67	8.67	8.67	8.33	24.46	145.41	175.43	185.33
T6 Mustard + Linseed (1:1)	8.67	8.67	8.67	8.33	23.50	141.00	171.16	182.35
T7 Mustard + Linseed (2:1)	8.33	8.33	8.33	8.33	23.00	140.66	170.33	180.90
T8 Mustard + Pea (1:1)	8.67	8.67	8.67	8.33	21.90	139.75	168.66	176.66
T9 Mustard + Pea (2:1)	8.67	8.67	8.67	8.67	21.45	138.50	165.43	175.33
SE(m) ±	0.138	0.093	0.132	0.145	0.390	2.122	2.047	1.962
C.D. at 5%	NS	NS	NS	NS	1.180	6.418	6.191	5.932

DAS: Day after Sowing; NS: Non Significant

Table 2. Effect of intercropping system on number branches, fresh and dry weight of Mustard

Treatment Combinations	**Number of primary branches/plant**				**Number of secondary branches/plant**			**Fresh weight per plant (g)**				**Dry weight per plant (g)**			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**	**60 DAS**	**90 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**90 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**90 DAS**	**At harvest**
T1 Sole mustard	3.83	8.75	9.08	9.18	28.25	29.25	29.25	26.30	265.50	280.50	270.78	5.26	53.10	60.00	55.16
T2 Mustard + Chickpea(1:1)	3.58	8.67	8.83	8.87	27.17	28.50	28.53	23.00	235.90	270.65	260.45	4.63	47.18	54.14	51.09
T3 Mustard + Chickpea(2:1)	3.50	8.33	8.75	8.78	27.08	28.33	28.42	22.50	225.30	269.59	259.65	4.50	45.06	53.12	50.13
T4 Mustard + Lentil (1:1)	3.83	8.75	8.92	8.93	28.00	29.08	29.08	24.99	255.00	279.85	268.79	5.12	51.50	58.17	54.16
T5 Mustard + Lentil (2:1)	3.75	8.67	8.92	8.92	27.75	28.67	28.67	24.50	245.67	277.90	265.86	5.03	49.13	56.18	53.17
T6 Mustard + Linseed (1:1)	3.45	8.33	8.67	8.68	26.67	27.67	27.67	22.00	220.50	272.89	256.80	4.40	44.10	52.18	49.16
T7 Mustard + Linseed (2:1)	3.33	8.33	8.58	8.58	26.00	27.00	27.00	21.30	212.67	267.50	254.63	4.27	42.53	51.33	48.32
T8 Mustard + Pea (1:1)	3.33	8.33	8.50	8.57	25.67	26.33	26.67	21.00	205.10	262.45	251.00	4.20	41.02	50.09	47.85
T9 Mustard + Pea (2:1)	3.00	8.00	8.33	8.33	25.00	26.00	26.00	20.00	201.80	258.30	250.89	4.00	40.36	49.26	47.25
SE(m) ±	0.048	0.113	0.150	0.159	0.468	0.538	0.319	0.326	2.370	3.204	2.919	0.084	0.759	0.766	0.567
C.D. at 5%	0.146	0.341	NS	NS	1.414	1.626	0.966	0.985	7.166	9.689	8.826	0.255	2.296	2.317	1.715

DAS: *Day after Sowing*; NS: *Non Significant*

Table 3. Effect of intercropping system on yield and profitability of Mustard

Treatment Combinations	Grain yield (t ha^{-1})	Mustard Equivalent yield (t ha^{-1})	Cost of cultivation (INR ha^{-1})	Gross income (INR ha^{-1})	Net income (INR ha^{-1})	B:C ratio
T1 Sole mustard	2.88	2.88	37267.00	188312.50	151045.50	5.05
T2 Mustard + Chickpea (1:1)	2.49	2.71	39402.00	177832.50	138430.50	4.51
T3 Mustard + Chickpea (2:1)	2.46	2.56	38116.00	168138.50	130022.50	4.41
T4 Mustard + Lentil (1:1)	2.53	2.77	37696.00	181697.00	144001.00	4.82
T5 Mustard + Lentil (2:1)	2.47	2.61	37020.00	171151.50	134131.50	4.62
T6 Mustard + Linseed (1:1)	2.41	2.75	37618.00	180452.50	142834.50	4.80
T7 Mustard + Linseed (2:1)	2.39	2.52	36943.00	165584.00	128641.00	4.48
T8 Mustard + Pea (1:1)	2.40	2.69	39402.00	176391.50	136989.50	4.47
T9 Mustard + Pea (2:1)	2.37	2.49	38116.00	163553.50	125437.50	4.29
SE(m) ±	0.039	0.043	-	-	-	-
C.D. at 5%	0.120	0.132	-	-	-	-

3.7 Grain Yield

The grain yield (t ha^{-1}) of mustard showed significant result among the different intercrop combinations. The maximum grain yield was recorded with sole mustard T1 (2.88) followed by T4 (2.53), T2 (2.49), T5 (2.47), T3 (2.46), T6 (2.41), T8 (2.40) and T7 (2.39) while minimum grain yield recorded in T9 (2.37) where mustard was intercropped with pea. These are due to more dry weight, number siliqua/pod/capsule, number of seeds per siliqua/pods/capsule as well as test weight. These results are corroborated by findings of Tuti et al. [26], Chaudhary et al. [30] and Srivastava et al. [31].

3.8 Mustard Equivalent Yield

The significantly highest mustard equivalent yield (2.88 t ha^{-1}) recorded in T1 (sole mustard) crop might be due to higher yield levels than other intercrops. Among the different intercropping treatments significantly higher mustard equivalent yield recorded in T4 (2.77 t ha^{-1}) and T6 (2.75 t ha^{-1}) due to high market price and higher yield of lentil and linseed compare to other intercrops. The findings are in the conformity with the findings of Roy et al. [32] and Singh et al. [33].

3.9 Gross Income

The gross income showed significant results in both sole planting and intercropping systems, and these two approaches were comparable to each other. However, it's worth noting that the sole crop system recorded a higher gross income than the intercropping system. Among different treatments maximum gross income recorded significantly in T1: sole mustard (INR 188312.50 ha^{-1}) followed by T4 (INR 181697.00 ha^{-1}) and T6 (INR 180452.50 ha^{-1}) due to higher yield dry weight of the produce. The findings are in the conformity with the findings of Tuti et al. [26].

3.10 Net Income

The net returns demonstrated significant differences in both sole planting and intercropping systems, with these two approaches being comparable to each other. However, it is noteworthy that the sole crop system yielded higher net returns than the intercropping system. Among different treatments significantly higher net returns recorded in T1: sole mustard (INR151045.50 ha^{-1}) followed by T4 (INR 144001.00 ha^{-1}) and T6 INR 142834.50 ha^{-1}) due to higher yield dry weight of the produce. The findings are in the conformity with the findings of Sahota and Sukhdev [34] and Abu-Bakar et al [35].

3.11 B: C Ratio

The benefit cost ratio showed significant result among the different intercrop combinations. The significantly maximum net returns was recorded with sole mustard T1 (5.05) followed by T4 (4.82), T6 (4.80), T5 (4.62), T2 (4.51) T7 (4.48) T8 (4.47) and T3 (4.41) and whereas, T9 (4.29) recorded minimum benefit cost ratio where mustard was intercropped with pea. The findings are in the conformity with the findings of Roy et al. [32] and Singh et al. [33].

4. CONCLUSION

A field experimental conducted during *rabi* season (2021-22) at student's instructional farm of C.S.A. University of Agriculture and Technology, Kanpur following conclusion can be done. Cultivation of sole mustard (T1) was superior over other different intercrops followed by T4. The combinations of Mustard + lentil gave the highest mustard equivalent yield followed by T6 and T2. The economic point of view the highest net returns from T1: sole mustard (INR 151045.50 ha^{-1}) followed by T4 and T6. The highest benefit cost ratio was fetched from the sole mustard (5.05) followed by T4 and T6. In conclusion, the results suggest that T: sole Mustard cultivation was the most productive and profitable in terms of net returns and benefit-cost ratio. However, the intercropping system of T4: Mustard and Lentil (1:1) also performed well and can be a viable option for farmers looking to diversify their crops and potentially increase yields while maintaining profitability.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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