<u>***Original Research Article***</u>

To Study the Suitable Combination of Indian mustard (*Brassica Juncea* L.) Based Intercropping System with Chickpea, Lentel, Linseed and Pea

Abstract:

Intercropping system enhances crop productivity and profitability 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 impact of intercropping ratios on plant population, height, primary branches, dry weight, and yield attributes in mustard intercropped with chickpea, lentil, linseed, and pea. Plant population of intercrops showed non-significant differences, but at later stages, a 1:1 ratio consistently led to higher plant populations. Plant height, primary branches, and dry weight were generally higher in the 1:1 ratio compared to the 2:1 ratio across all intercrops and growth stages. Yield attributes, including the number of pods/capsules and seeds per pod/capsule, favoured the 1:1 ratio. The highest yield was observed in the 1:1 ratio, contrasting with the minimum in the 2:1 ratio of mustard + intercrops. Overall, the 1:1 ratio demonstrated superior performance in terms of growth, yield attributes and yield, emphasizing the importance of intercrop ratio in optimizing crop growth and productivity.

Keywords: *Intercropping; Mustard; Chickpea; Pea; Lentil; Linseed; Growth; Yield*

1. Introduction

Current agriculture faces formidable challenges, including stagnating production due to declining factor productivity, soil health degradation, in-efficiencies in current production practices, resource scarcity, high cultivation costs, and low returns for farmers, a consequence of the adverse effects of the green revolution, which prioritizes maximum output over input efficiency (Jat *et al*., 2021). Meanwhile, per capita land availability is decreasing, intensifying the pressure to produce more food, feed, fiber, fuel, and fodder per unit area to meet the basic needs of a growing population (Popp *et al*., 2014). This challenge is exacerbated by climate change, introducing new threats to the sustainability of major cropping systems. While a horizontal increase in crop production is unfeasible, the enhancement of crop productivity per unit area is achievable through intercropping (Singh *et al*., 2016). Consequently, addressing the challenges posed by the overuse of natural resources and sustaining productivity requires improved crop management, specifically the inclusion of legume crops in crop rotations and intercropping legumes with cereals (Meena *et al*., 2018). Such practices offer numerous potential benefits compared to sole cropping systems (Venkateswarlu and Shanker, 2009).

Intercropping system serves as an effective strategy to enhance both the production and quality productivity of crops by cultivating two or more economically dissimilar crop species in distinct row combinations simultaneously on the same piece of land (Maitra *et al*., 2019). This practice significantly contributes to increased diversity in the cropping system (Bahadur *et al*., 2015). Intercropping is specifically characterized by the simultaneous cultivation of two or more dissimilar crops on the same piece of land in a distinct row arrangement, utilizing one crop as a base to which rows of an additional component crop are added (Layek *et al*., 2018). In India, intercropping is a time-honored practice, particularly under rainfed conditions, with the primary goals of augmenting total productivity per unit area and judiciously utilizing land resources and farming inputs, including labor (Babu *et al*., 2021). The successful development of economically viable intercropping systems relies heavily on the selection of compatible crops and the adoption of proper planting geometry (Sahoo *et al*., 2023). Consequently, the modern objective of intercropping is geared towards maximizing total productivity per unit area over time by cultivating more than one crop in the same field, with a primary focus on optimizing the use of environmental resources (Ryan *et al*., 2018). As with any cropping system, intercropping has its share of advantages and disadvantages. While research is ongoing, there is substantial evidence indicating that intercropping can significantly boost yields from a given land area (Himmelstein *et al*., 2017). Moreover, intercrops may necessitate lower levels of costly inputs through enhanced resource-use efficiency. A crucial advantage of intercropping lies in the increase in yield and sustainability, facilitated by the presence of another crop that may compensate for yield losses in the other crop due to adverse climatic conditions (Yu *et al*., 2022). The traditional practice of intercropping has gained renewed popularity in recent years, with adjustments made to planting patterns. Essentially, the intercropping system aids in mitigating the risk of insect and disease epidemics, overcoming the effects of unfavorable environmental conditions in agro-climatologically less stable regions, and optimizing the utilization of solar radiation and inputs such as fertilizer and water compared to sole cropping systems.Diversifying cropping systems is imperative to achieve higher yields and returns, ensuring soil health, environmental preservation, and meeting the daily food and feed requirements for both humans and animals (Sanderson *et al*., 2013).

The cultivation of mustard alongside various crops such as lentil, chickpea, pea, and linseed as intercrops is a common and beneficial practice (Shekhawat *et al*., 2012). When adopting an appropriate row ratio of mustard with oilseeds like linseed and legumes like lentil, pea, and chickpea for a specific area, farmers can efficiently and effectively utilize available resources (Pooniya*et al*., 2015). India stands as one of the world's leading oilseed-growing countries and holds the third position in the global vegetable oil economy, following only the USA and China. Oilseeds rank second after food grains in terms of both area and production. Presently, India contributes to approximately 13% of the world's oilseed area, 7% of production, and 10% of edible oilseed consumption (Mathur *et al*., 2023). The country relies heavily on oilseed crops, including groundnut, rapeseed-mustard, soybean, sunflower, niger, sesame, safflower, linseed, and castor, which collectively account for over 80% of the vegetable oil and fats requirement in India (Narayan, 2017). Oilseeds are predominantly cultivated under rainfed conditions and play a crucial role in supporting the livelihoods of small and marginal farmers in arid and semi-arid areas of the country.Mustard (Brassica juncea L.) holds the second position (28%) among oilseed crops in India, following soybean (36%), and is primarily grown for edible oil used in cooking and frying (Dubey *et al*., 2022). Recognized as oilseed brassicas, mustard has proven successful as an intercrop with various pulses and oilseeds across diverse agro-ecological zones in India. Additionally, it finds cultivation in specific tropical and sub-tropical regions during the winter season. Mustard exhibits a reasonable tolerance to moderate salinity, but its optimal growth and development occur in soils with a neutral pH. The byproducts of mustard, including oil cake as cattle feed and manure, green foliage as fodder for domestic animals, and young plants as a green vegetable, contribute significantly to dietary sulfur content (Kumawat *et al*., 2014). Linseed (*Linum usitatissimum* L.), also known as flax, holds prominence as a significant oilseed crop. Originating from the Old World, it was likely first cultivated in southern Asia and the Mediterranean region (Jhala and Hall, 2010). Linseed is a crucial rabi season crop, often cultivated under rainfed conditions and used in intercropping. Notably, its oil, with a high linolenic acid content ranging from 35% to 66%, is valuable for the production of items such as paints, inks, and varnishes.

Pulse crops play a pivotal role in agriculture due to their richness in proteins, carbohydrates, minerals, vitamins, and crude fiber, constituting a significant portion of the diet for the majority of vegetarian individuals in the country (Bessada *et al*., 2019). Beyond their nutritional value, pulses possess unique properties, such as the ability to maintain and restore soil fertility through biological nitrogen fixation (BNF) and improve soil physical properties through their deep root system and leaf fall. Chickpea (*Cicer arietinum* L.) is cultivated both in sole stands and mixed stands due to its diverse morphology, growth rhythm, and similar climatic requirements (Singh and Rana, 2006). As a cool-season legume crop, chickpea is sown as a winter crop in the tropics or as a spring or summer crop in temperate regions. Globally, chickpea ranks as the third most important pulse after dry beans and dry peas, but in India, it holds the highest cultivation share, covering 40% of the pulse-growing area. India stands out as the premier chickpea-growing country, contributing to 77% of the world's total area and production. Field pea (*Pisum sativum* L.) is another significant pulse crop cultivated over 6.5 million hectares worldwide, yielding approximately 10.2 million tonnes. The mature pea is highly nutritious, containing digestible protein (18-35%), starch (20-50%), sugars (4-10%), fat (0.6-1.5%), cellulose (2-10%), and essential minerals and vitamins like calcium, iron, phosphorus, Vit-A, C, B2, and B1 (Singh et al., 2014). The pea plant also serves as a valuable forage legume, utilized for hay, pasture, and silage. In semi-arid areas, field pea is employed for seed and green manure, making it a vital feed for animals and indispensable for efficient and economical livestock feeding. Tender pea seeds are used in soups, while canned, frozen, and dehydrated peas find common usage during off-seasons. Lentil, primarily grown in India, Canada, Turkey, USA, Syria, and Australia, holds the distinction of being the world's largest producer of pulses. Thriving well in sub-marginal lands with low inputs under water-limited conditions, lentil is often referred to as the "poor man's meat." Nutritionally, lentil seeds are valued for their high protein content (up to 30%) and serve as a rich source of vitamins and essential minerals (potassium, phosphorus, iron, magnesium, zinc), low in fat, and free from cholesterol. Lentil seeds comprise approximately 25-27% crude protein, 59% carbohydrates, 0.5% fat, 2.1% minerals, and a significant amount of vitamins. Given the above considerations, it becomes imperative to explore suitable crops and optimal row ratios to enhance productivity under intercropping systems. The objectives include determining compatible intercrops and row ratios for mustard, identifying suitable pulses for intercropping, analyzing the impact of intercrops on mustard's competition, and assessing 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. The geographic coordinates are approximately 26° 29' 35" North latitude and 80° 18' 25" East longitude, with an elevation of around 125.9 m above MSL 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.

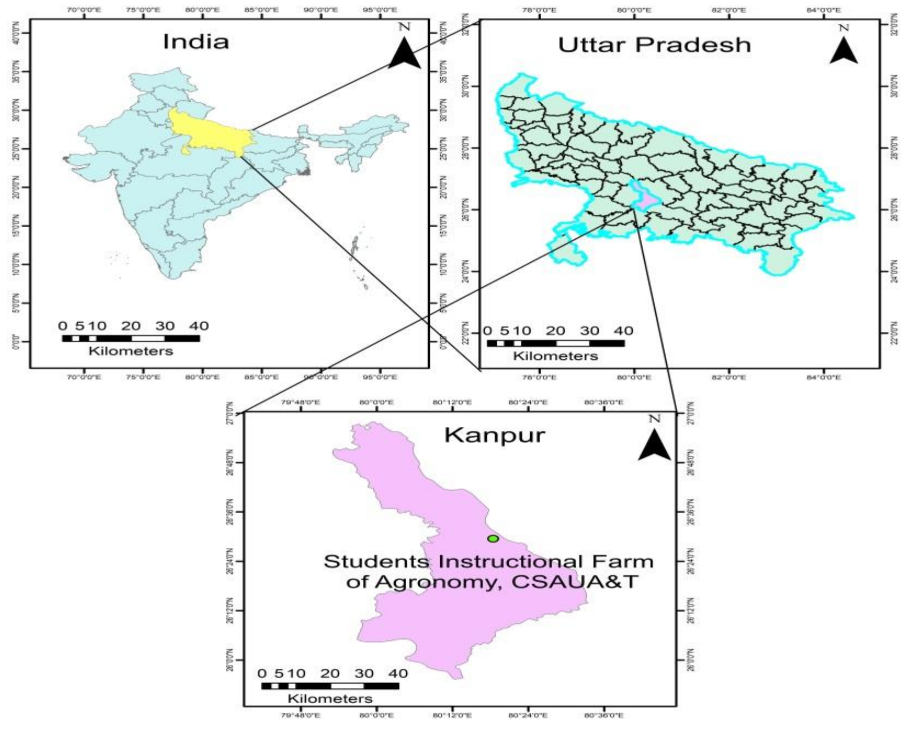

Fig. 1 Location Map of the Study Area

2.2 Climatic conditions:The weather data for the *Rabi* season 2021-22 was gathered from the Agro-meteorological Observatory located within the Department of Agronomy at CSAUA&T Kanpur. Climate, encompassing the amalgamation of weather conditions, extends its influence over specific regions and broader areas such as zones, states, countries, and continents, across varying timeframes like months, seasons, and years. In this particular zone, a semi-arid climate prevails, characterized by fertile alluvial soil. The annual rainfall measures approximately 937 mm, concentrated mainly from mid-June to September. Winters bring cooler temperatures, ranging between 2°C to 3°C, accompanied by occasional rain and frost from late December to mid-January. Conversely, May and June witness elevated temperatures, often soaring to 44°C to 47°C or even higher. Relative humidity remains consistently between 80-90% from July to March, gradually diminishing to 40-50% by the end of April and maintaining at 60% up to June.

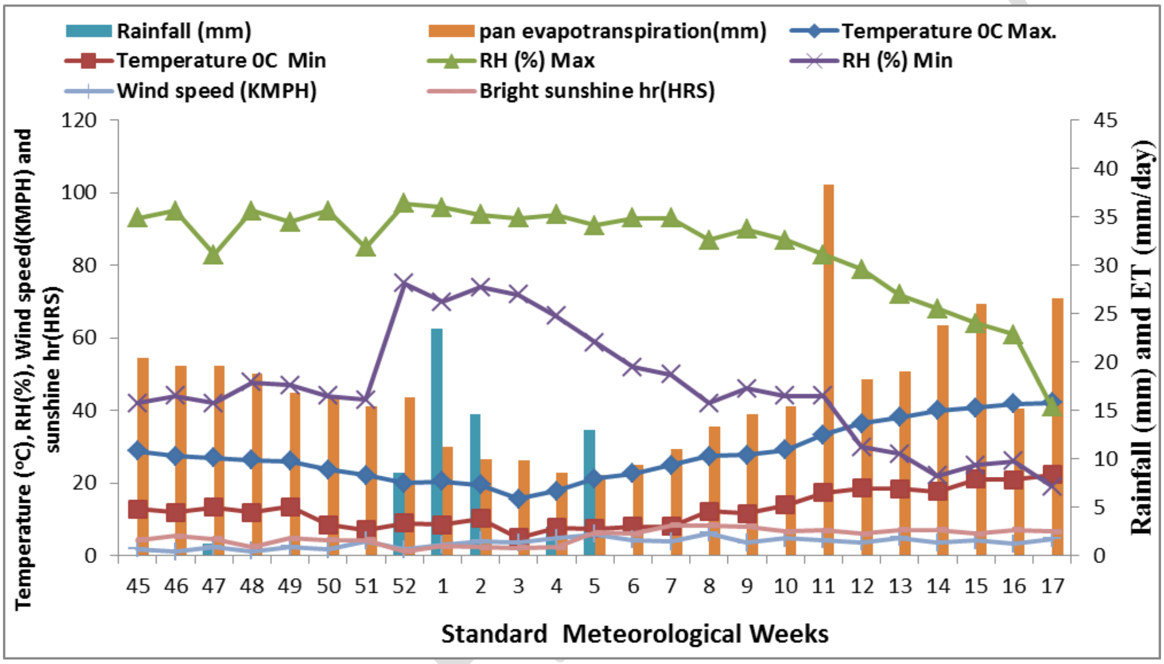

Fig 2. Details of Weather Data during Crop Season (2021-22)

2.3 Soil characteristics: The characteristics of soil play a pivotal role in shaping plant growth and, consequently, the overall yield. The experimental field's soil is categorized as sandy clay loam, with the following precise measurements: pH (7.30), EC (0.33 dsm^{-1}), Organic Carbon (0.43%), available nitrogen (215 kg ha^{-1}), P_2O_5 (16.5 kg ha^{-1}), K_2O (147 kg ha^{-1}), and S (10 ppm).

2.4 Experimental Details: The experiment was conducted using a Randomized Block Design with three replications. There were nine treatment combinations, namely 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). Each plot measured (18 m^2), with dimensions of 5.0 m in length and 3.6 m in width.

2.5 Crop Varieties:

2.1 Azad Mahak (Mustard):Chandra Shekhar Azad University of Agriculture & Technology (CSAUA&T), Kanpur (U.P.) introduced this variety, which matures in 120-

125 days during the *Rabi* season. Well-suited for cultivation throughout Uttar Pradesh, this variety boasts an oil content ranging from 41.6% to 42.1%, with a remarkable yield potential of 8.82 q ha^{-1}.

2.2 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.

2.3 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}.

2.4 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 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: Land preparation commenced after the harvest of the *kharif* crop, and pre-sowing irrigation was administered to facilitate proper seed germination. The field underwent one ploughing with a disc plough, followed by two cross ploughings using a tractor-drawn cultivator. Each ploughing was succeeded by planking to ensure soil firmness, friability, and a level surface conducive to seed germination. Layout planning was meticulously executed after land preparation. Fertilizers were applied according to the recommended doses for specific crops: Mustard (120:60:60), Chickpea (20:60:20), Lentil (20:60:20), Linseed (100:60:40) and Field Pea (20:60:20 kg ha^{-1}). The seed rates were 5.5 kg ha^{-1} for Mustard, 80 kg ha^{-1} for Chickpea, 40 kg ha^{-1} for Lentil, 30 kg ha^{-1} for Linseed and 80 kg ha^{-1} for Field Pea. Sowing of all five crops took place on October 28, 2021, on flat beds in defined row ratios by dropping seeds into furrows opened by a bullock-drawn plough. Mustard, Chickpea, Lentil, Linseed, and Field Pea were sown in a replacement series of intercropping with row spacing of 45 cm apart and plant spacing of 10 cm apart. In the replacement series, each crop is considered a component crop, and by sacrificing the plant population of one component crop, another crop is accommodated. Optimal plant populations (2, 22,222 ha^{-1}) were maintained in sole and intercropped treatment combinations [(1:1) ratio (1, 11,111 ha^{-1}) and treatment combination (2:1) ratio (1, 48,888 ha^{-1})]. Intercrops were sown according to the treatment in different row proportions. Extra and weak plants were manually uprooted at 20 days after sowing to maintain crop geometry. Gap filling was also conducted as needed to achieve the desired plant population. The crop was grown under irrigated conditions, and irrigation was applied based on the treatment. Flood method irrigation was carried out twice, once at the branching stage on December 15, 2021. Manual weeding occurred twice, first at 25 days after sowing and second at 45 days after sowing. Weeding operations also involved removing off-type plants. During the flowering period, the crop faced infestation by White Blister caused by the fungus Albugo candida. To control this infestation, Matco (metalaxyl 8% + mancozeb 64%) was sprayed. Harvesting took place when 80% of pods/siliqua turned yellowish brown, and the seed moisture content was around 38%. Initially, border rows were harvested, and the plants were set aside. Subsequently, net plot rows were harvested, especially in the morning when siliquae were slightly moisturized with night dew to prevent scattering. Harvesting was done manually with sickles. Harvested plants from net plots were bundled separately for each plot, sun-dried, and brought to the threshing floor. The produce of net plots was individually weighed and recorded before threshing. Threshing was performed with wooden sticks, and the seed weight from net plots was carefully recorded. Stover yield of each net plot was calculated by subtracting the grain yield from the total biological yield. To assess the impact of different treatments on the growth and development of the experimental crop, numerous observations were recorded from randomly selected tagged plants in each plot, excluding the border area. Growth parameters such as plant population, fresh and dry weight, plant height, number of primary and secondary branches, etc., were recorded at 30, 60, 90 days after sowing (DAS) and during harvesting. Yield attributing characters were also noted, including the number of siliquae/pods per plant and the number of seeds per siliquae/pod. Throughout the investigation, various studies were conducted on different plant traits.

2.7 Observations recorded: To enhance cost-effective precision, a methodical sampling strategy was implemented, focusing on data collection from five specifically tagged plants within each plot. Several parameters pertaining to mustard, including plant population, height, number of branches, dry weight, number of pods/plant, number of seeds/pod, test weight (g), grain yield, biological yield and harvest index were meticulously recorded on a per-plot basis. Subsequently, the gathered data underwent rigorous statistical analysis, employing the methodology delineated by Gomez and Gomez (1984), to evaluate potential significant differences among treatment means. The Least Significant Difference (LSD) test was then employed to compare treatment means at a 5% significance level.

3. Result and Discussion

3.1 Plant population: Plant population data were recorded after thinning at 30, 90 days after sowing (DAS), and at harvest (Table 1). The population of intercrops at 30, 60, and, 90 DAS, and at harvest, was found to be non-significant. At 30 DAS, the plant population of chickpea was the same in T2 (1:1) and T3 (2:1), measuring 9.33. However, at 60 DAS, 90 DAS, and at harvest, it was higher with a 1:1 ratio compared to the 2:1 ratio of intercrops. The plant population of lentil was consistently higher with a 1:1 ratio compared to the 2:1 ratio at 30, 60, 90 DAS, and at the harvest stage. Similarly, the plant population of linseed was recorded as higher with a 1:1 ratio compared to the 2:1 ratio at 30, 60, 90 DAS, and at the harvest stage. The plant population of peas followed the same trend, being higher with a 1:1 ratio compared to the 2:1 ratio at 30, 60, 90 DAS, and at the harvest stage.

3.2 Plant height: The plant height recorded at 30, 60, 90 DAS and at harvest (Table 2) which was found significant variation in different stages of intercrops. At 30 DAS plant height of chickpea recorded non-significant effect on plant height but at 60, 90 DAS and at harvest recorded significant effect on plant height. However, plant height was highest in 1:1 ratio than 2:1 ratio of mustard + chickpea at all the stages of crop growth. At 30 DAS plant height of lentil recorded non-significant effect on plant height but at 60, 90 DAS and at harvest recorded significant effect on plant height. However, plant height was highest in 1:1 ratio than 2:1 ratio of mustard + lentil at all the stages of crop growth. At 30 DAS plant height of linseed recorded non-significant effect on plant height but at 60, 90 DAS and at harvest recorded significant effect on plant height. However, plant height was highest in 1:1 ratio than 2:1 ratio of mustard + linseed at all the stages of crop growth. At 30 DAS plant height of pea recorded non-significant effect on plant height but at 60, 90 DAS and at harvest recorded significant effect on plant height. However, plant height was highest in 1:1 ratio than 2:1 ratio of mustard + pea at the all the stages of crop growth.The introduction of chickpea, lentil, linseed, and pea in mustard resulted in significantly lower plant height compared to the sole crop. This reduction in height could be attributed to increased intercrop competition for resources, which hampers overall crop growth. Similar findings of considerably higher plant height in sole mustard compared to various intercropping treatments were reported by (Choudhary *et al*., 2012), (Mandal *et al*., 2014), and (Nyasasi and Kisetu, 2014).

3.4 Number of branches/plant: The number of primary branches/plant of inter crops at 30, 60, 90 DAS and at harvest (Table 3) which was recorded significant result at all stages of crop growth. At 30, 60, 90 DAS and at harvest number of primary branches per plant was found maximum in 1: 1 ratio than 2:1 ratio at all the stages of plant growth. At 30, 60, 90 DAS and at harvest number of primary branches per plant was found maximum in 1: 1 ratio than 2:1 ratio at all the stages of plant growth. At 30, 60, 90 DAS and at harvest number of primary branches per plant was found maximum in 1: 1 ratio than 2:1 ratio at all the stages of plant growth. At 30, 60, 90 DAS and at harvest number of primary branches per plant was found maximum in 1: 1 ratio than 2:1 ratio at all the stages of plant growth. The present findings are in agreement with the results of (Singh *et al*., 2010) and (Singh *et al*., 2023).

3.5 Dry weight per plant (g): The dry weight per plant of intercrops at 30, 60, 90 DAS and at harvest (Table 4) which was showed significant variation at early growth stages of intercrops but non-significant at 60, 90 DAS and at harvest stages in all intercrops. Plant dry weight per plant of chickpea recorded significant result at 30 DAS whereas, it was found non-significant at 60, 90 DAS and at harvest stage in chickpea. The dry weight of chickpea is highest in the 1:1 ratio compared to the 2:1 ratio with the mustard crop throughout all stages of crop growth. Plant dry weight per plant of lentil recorded significant result at 30 DAS whereas, it was found non-significant at 60, 90 DAS and at harvest stage in lentil. The dry weight of lentil is highest in the 1:1 ratio compared to the 2:1 ratio with the mustard crop throughout all stages of crop growth. Plant dry weight per plant of linseed recorded significant result at 30 DAS whereas, it was found non-significant at 60, 90 DAS and at harvest stage in linseed. The dry weight of linseed is highest in the 1:1 ratio compared to the 2:1 ratio with the mustard crop throughout all stages of crop growth. Plant dry weight per plant of pea recorded significant result at 30 DAS whereas, it was found non-significant at 60, 90 DAS and at harvest stage in pea. The dry weight of pea is highest in the 1:1 ratio compared to the 2:1 ratio with the mustard crop throughout all stages of crop growth.Notably, the choice of a 1:1 ratio with mustard consistently resulted in higher dry weights for all intercrops across various stages of crop growth, while the significance of these differences diminished as the crops progressed to later growth stages.The present findings are in agreement with the results of (Sarlak *et al*., 2008), (Choudhary *et al*., 2012), and (Mandal *et al*., 2014).

Yield attributes of intercrops: The yield attributes of intercrops was significantly affected by different ratio.The number of pods/capsule per plant of all intercrops recorded significant result. The maximum number of pods/capsule per plant recorded with 1:1 than 2:1 ratio of mustard + intercrops. The number of seeds per pod/capsule of all intercrops recorded non-significant result. The maximum number of pods/capsule per plant recorded with 1:1 than 2:1 ratio of mustard + intercrops. Test weight does not show any significant difference in all the intercrops. However, maximum test weight recorded with 1:1 ratio lowest in 2:1 ratio of mustard + intercrops.Similar results were also reported by (Chongtham*et al*., 2018), (Singh *et al*., 2023) and (Devi *et al*., 2014).

Yield of intercrops: The data pertaining to grain, stover or straw and biological yield (Table 6) recorded significant result in all intercrops. However, maximum yield recorded with 1:1 ratio and minimum with 2:1 ratio of mustard + intercrops. The decline in intercropping yield can be attributed to the competition among crop plants for the efficient utilization of natural resources, leading to restricted growth of Indian mustard from the early stages to harvest. This restriction results in yield competition between the main and intercrops. Notably, among the row proportions, the 1:1 row proportion of intercrop with Indian mustard demonstrated significantly higher grain yield. This increase can be attributed to enhanced yield attributes, including a higher number of pods per plant, seeds per pod, and 1000-grain weight in Indian mustard.Similar results were also reported by (Chongtham*et al*., 2018) and (Devi *et al*., 2014).

Table 1. Effect of intercropping system on plant population of intercrops

Treatments	Plant population															
	Chickpea (C)				Lentil (L)				Linseed (Li)				Pea (P)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_2 Mustard + chickpea (1:1)	14.80	26.25	47.66	61.25	-	-	-	-	-	-	-	-	-	-	-	-
T_3 Mustard + chickpea (2:1)	14.03	24.10	45.75	59.25	-	-	-	-	-	-	-	-	-	-	-	-
T_4 Mustard + Lentil (1:1)	-	-	-	-	17.58	33.16	47.66	52.58	-	-	-	-	-	-	-	-
T_5 Mustard + Lentil (2:1)	-	-	-	-	17.11	31.75	45.25	50.15	-	-	-	-	-	-	-	-
T_6 Mustard + Linseed (1:1)	-	-	-	-	-	-	-	-	17.53	51.75	76.33	97.33	-	-	-	-
T_7 Mustard + Linseed (2:1)	-	-	-	-	-	-	-	-	16.50	50.50	68.65	91.66	-	-	-	-
T_8 Mustard + Pea (1:1)	-	-	-	-	-	-	-	-	-	-	-	-	20.73	47.91	60.41	71.66
T_9 Mustard + Pea (2:1)	-	-	-	-	-	-	-	-	-	-	-	-	20.12	46.00	56.45	67.66
SE(m)±	**0.187**	**0.065**	**0.285**	**0.285**	**0.567**	**1.027**	**0.146**	**0.166**	**0.278**	**0.186**	**0.805**	**0.628**	**0.366**	**0.186**	**0.169**	**0.501**
C.D. at 5%	**NS**	**0.426**	**1.866**	**1.866**	**NS**	**0.538**	**0.955**	**1.087**	**NS**	**1.218**	**5.276**	**4.112**	**NS**	**1.218**	**1.107**	**3.284**

Table 2. Effect of intercropping on plant height of intercrops

Treatments	Plant height (cm)															
	Chickpea (C)				Lentil (L)				Linseed (Li)				Pea (P)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_2 Mustard + chickpea (1:1)	14.80	26.25	47.66	61.25	-	-	-	-	-	-	-	-	-	-	-	-
T_3 Mustard + chickpea (2:1)	14.03	24.10	45.75	59.25	-	-	-	-	-	-	-	-	-	-	-	-
T_4 Mustard + Lentil (1:1)	-	-	-	-	17.58	33.16	47.66	52.58	-	-	-	-	-	-	-	-
T_5 Mustard + Lentil (2:1)	-	-	-	-	17.11	31.75	45.25	50.15	-	-	-	-	-	-	-	-
T_6 Mustard + Linseed (1:1)	-	-	-	-	-	-	-	-	17.53	51.75	76.33	97.33	-	-	-	-
T_7 Mustard + Linseed (2:1)	-	-	-	-	-	-	-	-	16.50	50.50	68.65	91.66	-	-	-	-
T_8 Mustard + Pea (1:1)	-	-	-	-	-	-	-	-	-	-	-	-	20.73	47.91	60.41	71.66
T_9 Mustard + Pea (2:1)	-	-	-	-	-	-	-	-	-	-	-	-	20.12	46.00	56.45	67.66
SE(m)±	**0.187**	**0.065**	**0.285**	**0.285**	**0.567**	**1.027**	**0.146**	**0.166**	**0.278**	**0.186**	**0.805**	**0.628**	**0.366**	**0.186**	**0.169**	**0.501**
C.D. at 5%	**NS**	**0.426**	**1.866**	**1.866**	**NS**	**0.538**	**0.955**	**1.087**	**NS**	**1.218**	**5.276**	**4.112**	**NS**	**1.218**	**1.107**	**3.284**

Table 3. Effect of intercropping on number of primary branches/plant of intercrops

Treatments	Number of branches per plant															
	Chickpea (C)				Lentil (L)				Linseed (Li)				Pea (P)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_2 Mustard + chickpea (1:1)	3.15	5.33	5.66	5.78	-	-	-	-	-	-	-	-	-	-	-	-
T_3 Mustard + chickpea (2:1)	2.83	4.57	5.15	5.33	-	-	-	-	-	-	-	-	-	-	-	-
T_4 Mustard + Lentil (1:1)	-		-	-	3.65	5.17	6.25	6.28	-	-	-	-	-	-	-	-
T_5 Mustard + Lentil (2:1)	-		-	-	3.00	4.67	5.83	5.83	-	-	-	-	-	-	-	-
T_6 Mustard + Linseed (1:1)	-		-	-	-	-	-	-	2.83	6.17	7.33	7.35	-	-	-	-
T_7 Mustard + Linseed (2:1)	-		-	-	-	-	-	-	2.30	5.50	6.25	6.25	-	-	-	-
T_8 Mustard + Pea (1:1)	-		-	-	-	-	-	-	-	-	-	-	2.02	2.75	3.09	3.12
T_9 Mustard + Pea (2:1)	-		-	-	-	-	-	-	-	-	-	-	1.92	2.33	2.91	3.01
SE(m)±	**0.033**	**0.008**	**0.077**	**0.046**	**0.005**	**0.011**	**0.067**	**0.060**	**0.004**	**0.013**	**0.163**	**0.011**	**0.006**	**0.004**	**0.014**	**0.010**
C.D. at 5%	**0.218**	**0.054**	**0.507**	**0.302**	**0.033**	**0.075**	**0.438**	**0.393**	**0.025**	**0.082**	**1.065**	**0.071**	**0.041**	**0.026**	**0.093**	**0.068**

Table 4. Effect of intercropping on dry weight (g) per plant of intercrops

Treatments	Dry weight per plant (g)															
	Chickpea (C)				Lentil (L)				Linseed (Li)				Pea (P)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_2 Mustard + chickpea (1:1)	0.64	4.68	6.96	6.38	-	-	-	-	-	-	-	-	-	-	-	-
T_3 Mustard + chickpea (2:1)	0.57	4.10	6.65	6.17	-	-	-	-	-	-	-	-	-	-	-	-
T_4 Mustard + Lentil (1:1)	-	-	-	-	0.41	1.17	1.55	1.42	-	-	-	-	-	-	-	-
T_5 Mustard + Lentil (2:1)	-	-	-	-	0.34	1.00	1.44	1.39	-	-	-	-	-	-	-	-
T_6 Mustard + Linseed (1:1)	-	-	-	-	-	-	-	-	0.32	4.04	5.83	5.65	-	-	-	-
T_7 Mustard + Linseed (2:1)	-	-	-	-	-	-	-	-	0.33	3.73	5.27	5.18	-	-	-	-
T_8 Mustard + Pea (1:1)	-	-	-	-	-	-	-	-	-	-	-	-	0.89	8.13	8.56	8.39
T_9 Mustard + Pea (2:1)	-	-	-	-	-	-	-	-	-	-	-	-	0.79	7.83	8.12	8.03
SE(m) ±	**0.007**	**0.165**	**0.111**	**0.053**	**0.006**	**0.002**	**0.020**	**0.011**	**0.003**	**0.010**	**0.069**	**0.082**	**0.009**	**0.248**	**0.033**	**0.137**
C.D. at 5%	**0.048**	**NS**	**NS**	**NS**	**0.039**	**NS**	**NS**	**NS**	**0.022**	**NS**	**0.452**	**NS**	**0.058**	**NS**	**NS**	**NS**

Table5.Effectofintercroppingonyield attributes of intercrops

Treatment Combinations	Number of pods per plant				Number of seeds per pod				Test weight (g)			
	C	**L**	**Li**	**P**	**C**	**L**	**Li**	**P**	**C**	**L**	**Li**	**P**
T_2 Mustard + Chickpea (1:1)	18	-	-	-	2.00	-	-	-	187.82	-	-	-
T_3 Mustard + Chickpea (2:1)	17	-	-	-	1.66	-	-	-	175.16	-	-	-
T_4Mustard + Lentil(1:1)	-	16	-	-	-	2.00		-	-	19.16	-	-
T_5 Mustard + Lentil(2:1)	-	14	-	-	-	2.00		-	-	18.51	-	-
T_6 Mustard + Linseed(1:1)	-	-	248	-	-	-	9.33	-	-	-	4.65	-
T_7 Mustard + Linseed(2:1)	-	-	232	-	-	-	9.00	-	-	-	4.35	-
T_8 Mustard + Pea(1:1)	-	-	-	16	-	-	-	4.66	-	-	-	205.05
T_9 Mustard + Pea(2:1)	-	-	-	15	-	-	-	4.33	-	-	-	200.93
SE(m) ±	**0.144**	**0.112**	**1.387**	**0.150**	**0.033**	**0.038**	**0.108**	**0.049**	**3.112**	**0.271**	**0.087**	**6.144**
C.D. at 5%	**0.944**	**0.734**	**9.090**	**0.980**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 6. Effect of intercropping on yield of intercrops

Treatment Combinations	Biological Yield (q/ha)				Grain Yield (q/ha)				Straw yield (q/ha)			
	C	**L**	**Li**	**P**	**C**	**L**	**Li**	**P**	**C**	**L**	**Li**	**P**
T_2 Mustard + Chickpea (1:1)	8.887	-	-	-	2.666	-	-	-	6.221	-	-	-
T_3 Mustard + Chickpea (2:1)	4.533	-	-	-	1.325	-	-	-	3.208	-	-	-
T_4Mustard + Lentil(1:1)	-	8.125	-	-	-	2.440	-	-	-	5.685	-	-
T_5 Mustard + Lentil(2:1)	-	4.345	-	-	-	1.425	-	-	-	2.920	-	-
T_6 Mustard + Linseed(1:1)	-	-	11.655	-	-	-	3.500	-	-	-	8.155	-
T_7 Mustard + Linseed(2:1)	-	-	5.994	-	-	-	1.400	-	-	-	4.594	-
T_8 Mustard + Pea(1:1)	-	-	-	12.920	-	-		3.880	-	-	-	9.040
T_9 Mustard + Pea(2:1)	-	-	-	5.998	-	-		1.680	-	-	-	4.318
SE(m) ±	**0.098**	**0.148**	**0.101**	**0.244**	**0.046**	**0.009**	**0.051**	**0.079**	**0.121**	**0.058**	**0.117**	**0.181**
C.D. at 5%	**0.639**	**0.972**	**0.663**	**1.601**	**0.303**	**0.057**	**0.332**	**0.519**	**0.796**	**0.382**	**0.767**	**1.186**

CONCLUSION

A field experiment conducted during the rabi season (2021-22) at the Student's Instructional Farm of C.S.A. University of Agriculture and Technology, Kanpur, leads to the following conclusions. In conclusion, the impact of intercropping ratios on various parameters in mustard intercropped with chickpea, lentil, linseed, and pea. Initially, plant population differences were non-significant, but a consistent trend favouring the 1:1 ratio emerged at later stages. Across all intercrops and growth stages, plant height, primary branches, and dry weight were consistently higher in the 1:1 ratio, indicating its superiority. Yield attributes, such as the number of pods/capsules, seeds per pod/capsule, and test weight, also favoured the 1:1 ratio. The maximum overall yield was observed in the 1:1 ratio, attributed to enhanced yield attributes in Indian mustard. These findings highlight the significance of balanced intercropping ratios for optimizing crop growth and productivity.

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