

Performance of Indian mustard (*Brassica juncea*) under different intercropping systems in Central plain zone of Uttar Pradesh

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ABSTRACT

The field experiment was carried out during winter (*rabi*) season of 2021–22 on Students' Instructional Farm of C.S. Azad University of Agriculture & Technology, Kanpur to assess the performance of Indian mustard under intercropping systems with chickpea, linseed, lentil and pea. The experiment was laid out in Randomized Block Design with 9 treatment combinations replicated thrice. These treatments included Sole Mustard (T₁), Mustard: Chickpea (T₂ 1:1 and T₃ 2:1), Mustard + Lentil (T₄ 1:1 and T₅ 2:1), Mustard + Linseed (T₆ 1:1 and T₇ 2:1), and Mustard + Field Pea (T₈ 1:1 and T₉ 2:1). The results revealed that yield attributes and yield of mustard was significantly higher in sole Mustard and Mustard + Lentil (1:1) intercropping system. The maximum number of branches/plant (37, 38.33 at 30 and 90 DAS, respectively), siliquae/plant (380), seeds/silique (16), test weight (4.89 g), seed yield (2.89 t/ha), stover yield (6.80 t/ha), biological yield (9.68 t/ha), and harvest index (29.80%) were recorded in T₁ (sole Mustard). Among intercropping system T₄ (Mustard + Lentil, 1:1) resulted the maximum number of branches/plant (36.75, 38 at 30 and 90 DAS, respectively), siliquae/plant (375), seeds/silique (16), test weight (4.84 g), seed yield (2.53 t/ha), stover yield (5.90 t/ha), biological yield (8.43 t/ha), harvest index (30.03%) and mustard equivalent yield (2.77 t/ha).

Key words: Chickpea, Intercropping system, Lentil, Linseed, Mustard, Pea, Productivity

Modern agriculture faces challenges such as stagnant production, declining factor productivity, soil degradation, inefficient practices, resource scarcity, high cultivation costs, and low returns to farmers (Kumar *et al.*, 2021). Besides, per capita land availability is decreasing, intensifying the pressure to produce more with limited space, climate change adds new threats like drought, storms, heat waves, rising sea levels, melting glaciers and warming ocean. Horizontal crop production expansion is impractical; the key lies in increasing productivity per unit area through practices like intercropping. To address resource overuse and sustain productivity, incorporating legume crops in rotations and intercropping with cereals offers

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potential benefits over sole cropping systems. Intercropping, the simultaneous cultivation of diverse crops in distinct row combinations on the same land enhances productivity and quality. Widely practiced in India, especially in rainfed regions, it aims to optimize land use and inputs (Ananthi *et al.*, 2017). Successful intercropping depends on selecting compatible crops and proper planting geometry. The practice reduces risks from pests, diseases, and adverse environmental conditions, utilizing resources more efficiently and thereby increasing yields, sustainability, and resource-use efficiency (Kuyah *et al.*, 2021). In India, intercropping, such as combining mustard with lentils, chickpea, pea, and linseed, is crucial for efficient resource utilization in oilseed cultivation, contributing significantly to the country's vegetable oil economy. Mustard (*Brassica juncea* L.), the second-largest oilseed crop in India, is used for edible oil in cooking and frying. It's successfully intercropped with various pulses and oilseeds in diverse agro-ecological zones, thriving in certain tropical and sub-tropical regions as a winter season crop (Sharma and Thakral, 2023). Mustard tolerates moderate salinity, preferring neutral pH soil for optimal growth. The by-products of mustard, such as oil cake, serve as both cattle feed and manure.

The green foliage is used as fodder, and young plants are consumed as a green vegetable, providing essential sulfur in the diet. Linseed (*Linum usitatissimum* L.), also known as flax, is a significant oilseed crop likely first cultivated in southern Asia and the Mediterranean region. With high linolenic-acid content (35–66%), linseed oil is valuable for products like paints, inks, and varnishes (Tripathy *et al.*, 2024).

Pulse crops are vital in agriculture, as they are rich in proteins, carbohydrates, minerals, vitamins, and crude fiber, forming a significant part of the diet for a large population of vegetarian individuals (Kamboj and Nanda, 2018). Additionally, pulses play a unique role in maintaining and restoring soil fertility through biological nitrogen fixation (BNF). Their deep root system and leaf fall contribute to conserving and improving the physical properties of the soil. Chickpea (*Cicer arietinum* L.) is grown both in sole and mixed stands due to its diverse morphology and growth rhythm, suitable for various climates (Das *et al.*, 2017; Meena *et al.*, 2024). As a cool-season legume, it serves as a winter crop in the tropics and a spring or summer crop in temperate regions. India is the leading chickpea producer, contributing to 77% of the world's total production (Raina *et al.*, 2019). Field pea (*Pisum sativum* L.) is a crucial pulse crop cultivated over 6.5 million ha globally, producing approximately 10.2 million tonnes. Mature peas are 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 (Prajapati *et al.*, 2024). Field pea serves multiple purposes, acting as forage for animals in hay, pasture, and silage, while in semi-arid areas; it is used for seed and green manure. Lentil (*Lens culinaris* Medik.), a major pulse crop, is prominently grown in India, Canada, Turkey, USA, Syria, and Australia (Laskar *et al.*, 2019). Lentil thrives in sub-marginal lands with low inputs, particularly under water-limited conditions, earning its nickname as the “poor man's meat. Nutritionally, lentil seeds are valued for their high protein content (up to 30%), vitamins, and essential minerals, being low in fat and cholesterol-free. To maximize returns per unit land area, intercropping of suitable crop with optimum row ratio is crucial. Hence, the experiment was undertaken with an objective to identify most compatible intercrops and row ratios for mustard.

The field experiment was conducted at Chandra Shekhar Azad University of Agriculture and Technology in Kanpur, Uttar Pradesh, India during *rabi* season of 2021–22 on Student's Instructional Farm (SIF), situated in the central region of North India's sub-tropical semi-arid tract (26° 29' 35" N latitude, 80° 18' 25" E longitude). The location is Gangetic plain at an elevation of approximately

125.9m above MSL. Kanpur experiences a semi-arid climate with fertile alluvial soil, receiving around 937mm of annual rainfall, mainly from mid-June to September. Minimum temperature winters range from 2°C to 3°C, with occasional rain and frost from late Dec. to mid-January and May and June are the hottest months reaching 44°C to 47°C or higher. Relative humidity ranges from 80–90% from July to March, decreasing to 40–50% by April end and staying at 60% up to June. The experimental field soil is sandy clay loam with specific measurements: pH (7.30), EC (0.33 ds/m), Organic Carbon (0.43%), available N (215 kg/ha), available P (16.5 kg/ha), available K (147. Kg/ha), and S (10 ppm). The experiment were laid out in Randomized Block Design with three replications, having 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), T₉ Mustard + Field Pea (2:1). Crop varieties included ‘Azad Mahak’ (Mustard), ‘Uma’ (Linseed), ‘Avrodhi’ (Chickpea), ‘KL-320’ (Lentil), and ‘Sapna’ (Field Pea). Field preparation began post-kharif crop harvest, involving pre-sowing irrigation for seed germination. Fertilizers were applied as recommended for each crop and sowing was done on October 28, 2021, with specified row ratios and plant spacing in a replacement series for intercropping. 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. Harvesting was done manually when pods/silique turned yellowish brown having around 38% moisture content. Harvested plants were sun-dried and brought to the threshing floor. Threshing was, done by using wooden sticks, and seed weight was recorded. Stover yield was calculated by subtracting seed weight from the total biological yield. Specifically, data were gathered from five identified plants within each plot. Various mustard-related parameters, viz., growth and yield were recorded on per-plot basis. Subsequently, the collected data underwent appropriate statistical analysis following the method detailed by to evaluate potential significant differences among treatment means. The Least Significant Difference (LSD) test was employed to compare the treatment means at 5% significance level.

The number of branches per plant of mustard recorded significant differences at 60 and 90 DAS (Table 1). The maximum number of primary branches per plant of mustard was found in T₁ (sole mustard). In intercrops the maximum number of branches/plant was observed in T₄ (Mustard + Lentil; 1:1), which was significantly higher among all intercropping treatments. Number of siliquae/plant and seeds/silique exhibited a significant difference among

Table 1. Effect of intercropping systems on yield attributes of mustard

Treatment	Branches/plant		Siliquae/plant	Seeds/siliquae	Test weight (g)
	60 DAS	90 DAS			
T ₁ Sole mustard	37.00	38.33	380.00	16.00	4.89
T ₂ Mustard + Chickpea (1:1)	35.84	37.33	360.50	15.66	4.81
T ₃ Mustard + Chickpea (2:1)	35.41	37.08	355.33	16.00	4.75
T ₄ Mustard + Lentil (1:1)	36.75	38.00	375.00	16.00	4.84
T ₅ Mustard + Lentil (2:1)	36.42	37.59	365.66	16.00	4.81
T ₆ Mustard + Linseed (1:1)	35.00	36.34	350.00	16.00	4.36
T ₇ Mustard + Linseed (2:1)	34.33	35.58	344.33	15.66	4.32
T ₈ Mustard + Pea (1:1)	34.00	34.83	339.66	15.66	4.20
T ₉ Mustard + Pea (2:1)	33.00	34.33	335.33	15.33	4.15
SEm±	0.56	0.33	3.380	0.263	0.067
CD (P=0.05)	1.692	1.00	10.221	NS	0.202

various intercrops. In mustard, the siliqua/plant and seeds/siliqua was significantly higher in T₁, followed closely by T₄. Both T₁ and T₄ were statistically at par but significantly superior over other combinations of mustard intercrops. However, the lowest results were recorded when mustard was intercropped with pea (T₉). Test weight (4.88) was the maximum in sole mustard crop, followed by T₄, T₅, T₂ and T₃ which were statistically at par but significantly superior over rest of the intercrop combinations. However, the minimum test weight in mustard crop recorded where mustard was grown with pea (4.20 and 4.15 g). The intercropping system's effect on yield attributes by optimizing resource use, managing pests and diseases were more effective due to modifying the microclimate, enhancing biodiversity, providing yield stability, influencing competition and facilitation among crops, incorporating beneficial crop rotation effects, and improving overall soil structure. Similar findings were reported by Devi *et al.* (2014), Patel *et al.* (2022) and Singh *et al.* (2016).

The seed, stover, biological yield and harvest index (Table 2) of mustard showed significant variations among

the different intercrop combinations. The significantly maximum yield was produced by sole mustard T₁ followed by T₄, T₂, T₅ and T₃ whereas T₉ recorded the minimum yield where mustard was intercropped with pea. The intercropping system influence yield by optimizing resource allocation and interactions among different crops contribute to a more balanced and resilient agricultural system, affecting the distribution of yields and overall crop performance. The intercrop combinations exhibited notable variations, with the mustard equivalent yield showing statistical significance. The highest mustard equivalent yield (MEY) was recorded in T₁ (sole mustard) crop, possibly attributed to its higher yield levels compared to other intercrops. Among the various intercropping system, significantly higher mustard equivalent yields were observed in T₄ and T₆ attributed to the combination of high market prices and the superior yields of lentil and linseed compared to other intercrops. These findings align with the results reported by Devi *et al.*, 2014; Kour *et al.*, 2015 and Tripathi *et al.*, 2005.

Intercropping significantly influences crop productivity.

Table 2. Effect of intercropping systems on productivity of mustard

Treatment	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	MEY (t/ha)
T ₁ Sole mustard	2.885	6.795	9.680	29.80	2.885
T ₂ Mustard + Chickpea (1:1)	2.499	5.822	8.321	30.03	2.715
T ₃ Mustard + Chickpea (2:1)	2.460	5.731	8.191	30.03	2.567
T ₄ Mustard + Lentil (1:1)	2.532	5.899	8.431	30.03	2.774
T ₅ Mustard + Lentil (2:1)	2.472	5.759	8.231	30.03	2.613
T ₆ Mustard + Linseed (1:1)	2.410	5.615	8.025	30.03	2.755
T ₇ Mustard + Linseed (2:1)	2.390	5.568	7.958	30.03	2.528
T ₈ Mustard + Pea (1:1)	2.400	5.592	7.992	30.03	2.693
T ₉ Mustard + Pea (2:1)	2.370	5.522	7.892	30.03	2.497
SEm±	0.039	0.105	0.076	0.230	0.043
CD (P=0.05)	0.120	0.318	0.229	NS	0.132

The study focused on the performance of Indian mustard within an intercropping system with chickpea, linseed, lentil, and field pea. The higher yield attributes and yield of mustard were observed with the sole mustard (T₁). However, in the intercropping system Mustard + Lentil; 1:1 (T₄) showed close noteworthy results. These results underscore the potential of intercropping, specifically the Mustard + Lentil (1:1) system, as an effective strategy to enhance crop productivity and economic viability in the cultivation of Indian mustard during winter season.

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