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Agroecological Synergies of Conservation Agriculture and Organic Nutrient Management Practices for Sustainable Mustard (*Brassica juncea* L.) Production

Gummadala Kasirao[1], Shiv Singh Tomar[2], Perli Himavarsha[3], Amarnath Singh[4] and Pradipta Ranjan Pradhan[5]

[1,2,3,4]Department of Agronomy, School of Agricultural Sciences, G.D. Goenka University, Sohna, India
[5]Assistant Prof, Department of Soil Sciences, School of Agricultural Sciences, G.D. Goenka University, Sohna, India

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ABSTRACT

Mustard (*Brassica juncea* L.) is a major oilseed crop with substantial status for edible oil and livestock feed, yet its productivity in India relics behind the global productivity because of poor soil fertility, inconsistent rainfall and unhinged nutrient management. Inadequate research intends to further explore the synergetic impact of conservation agriculture (CA) and organic nutrient management on mustard under semi-arid Indian conditions. To address the gap, a two-year field experiment was carried out at G.D. Goenka University, Haryana, to assess twelve treatment combinations involving no-tillage, crop residue retention, mulching and organic inputs such as poultry manure, farmyard manure, vermicompost and egg amino acid. The results suggest that the combination of no-tillage with egg amino acid (1 L/ha) and poultry manure (4 t/ha) (T) significantly improved mustard growth, yield and oil content. T recorded the maximum plant height (183.91 cm), number of leaves (30.67) and branches per plant (17.87) at harvest. Similarly, yield-contributing attributes such as siliquae per plant (187.20), seeds per siliqua (12.88), pod length (6.18 cm) and 1000-seed weight (5.21 g) were enhanced, leading to the maximum grain yield (20.53 q/ha), straw yield (47.40 q/ha), and oil content (37.62%). The greater performance under T is ascribed to amended soil structure, enhanced moisture retention, microbial activity and constant nutrient accessibility. These findings specify that integrating conservation agriculture with organic nutrient sources can deliver a sustainable and efficient strategy for improving mustard productivity and seed quality in resource-limited environments.

Keywords: *Mustard, Conservation agriculture, Growth, Yield, Quality, Nutrient management, Sustainable agriculture*

Introduction

Mustard (*Brassica spp.*) is an imperative oilseed crop cultivated globally for its edible oil, condiment and fodder value. It underwrites pointedly to total vegetable oil production, standing third subsequently soybean and palm. The crop's malleability to varied agro-climatic conditions and short growth duration make it an essential part of sustainable agricultural systems. Its oil is amusing in unsaturated fatty acids, while the residual oilcake obliges as a valuable protein source for livestock feed. Worldwide, mustard

([1,3]PhD Scholar, [2]Prof & Dean, [4]Prof & Head, [5]Assistant Prof) and rapeseed account for about 70 million tonnes annually, with India, China, Canada and the European Union being key producers (FAOSTAT, 2024; Sharma *et al.,* 2025). In India, mustard is cultivated in nearly 8 million hectares, with production of around 12.5 million tonnes per annum, contributory about 1/3 of total oilseed production (DACNET, 2024). It is largely cultivated in states like Rajasthan, Haryana, Madhya Pradesh, Uttar Pradesh and Gujarat. In spite of its importance, the national productivity (1.5-1.6 t/ha) remains lessthan the global productivity because of deprived soil fertility, inconsistent rainfall, inadequate irrigation, and unbalanced nutrient use (Bhinda *et al.,* 2023; Singh *et al.,* 2024). With mounting demand for edible oils and increasing environmental alarms, there is an imperative need to augment mustard productivity through eco-friendly and resource competent practices.

Conservation agriculture (CA) offers a feasible method for sustainable intensification. Its central ideologies, least soil disturbance, enduring soil cover, and crop diversification aid in conserving resources while preserving yield constancy (Sharma *et al.,* 2025). Espousal of CA progresses soil structure, water-use efficacy, and nutrient cycling while taming erosion and greenhouse gas emissions (Parihar *et al.,* 2018). Similarly, organic nutrient management has increased attention as a substitute to chemical fertilizers, which have led to soil degradation and nutrient imbalances in various intensive systems (Craswell, 2021; Abdel Rahman *et al.,* 2022). Organic inputs such as farmyard manure (FYM), vermicompost, *Panchagavya*, and *Jeevamrutham* augment soil microbial activity, expand organic carbon, and sustain nutrient release (Patel and Gangwar, 2023; Sharma *et al.,* 2024). Mixing CA with organic nutrient sources can consequently produce a biologically vigorous and resilient soil micro-environment favourable for mustard growth as well as productivity.

Nevertheless, inadequate research has been done on the combined properties of CA and organic nutrient management on oilseed crops under Indian agro-ecological conditions. Maximum studies have focused distinctly on tillage systems or organic inputs, with minimal evidence on their synergetic impact on soil biological health, nutrient-use efficacy and crop performance (Jat *et al.,* 2024). Furthermore, region-specific assessments for mustard, predominantly in semi-arid areas, are rare. Hence forth, the current study was commenced to evaluate the impact of conservation and organic management practices on growth, yield and quality attributes of mustard. Integrating these tactics is anticipated to improve productivity, progress soil fertility, and diminish the necessity for artificial inputs. The results will offer practical perceptions for sustainable mustard cultivation and ascribe to national primacies of soil health restoration, resource efficacy and self-sufficiency in edible oil production.

Research Methodology

Experimental Site and Soil Characteristics

Two-year field research was carried out during the *rabi* seasons of 2023 and 2024 at the Agronomy Research Farm, School of Agricultural Sciences, G.D. Goenka University, Sohna, Haryana (28°152 N, 77°062 E; 211 m MSL). The experimental site soil was sandy loam in texture, slightly alkaline (pH 7.9) with normal EC (0.14 dS/m), low in organic carbon (0.44%), low in range of available nitrogen (223 kg/ha), medium range in phosphorus (20.8 kg/ha) and high in range of potassium (411 kg/ha). Composite soil samples were collected from the 0–15 cm depth prior to sowing and analyzed for physicochemical properties.

Experimental Design and Management

The field experiment was laid out in a Randomized Block Design (RBD) with 12 treatment combinations as shown in the table .1, that were replicated thrice, a total of 36 plots. Each plot measured 4 × 3 m (net plot size of 12 m^2) with 0.5 m bunds and 1 m irrigation channels. The treatment combination comprised different conservation agriculture practices (crop residue retention, no-tillage and mulching) that were integrated with organic nutrient sources such as farmyard manure (FYM), vermicompost, and poultry manure, either alone or supplemented with organic formulations like *Panchagavya*, *Jeevamruth*, and egg amino acid. Mustard variety (*Brassica juncea* L. cv. PM-30) was used as the test crop for all treatments. Land preparation involved one rotavator pass followed by levelling with a plank. Organic manures were incorporated 10 days before sowing as per treatment. Mustard seeds were manually sown at a spacing of 30 × 15 cm and a depth of 5 cm.

Observations and Data Recording

Observations on growth, yield and quality parameters were recorded from five randomly selected and tagged plants in each plot at different growth stages. Plant height (cm) was measured from the base of the stem to the tip of the main shoot at 30, 60, and 90 days after sowing (DAS) and at harvest. The number of leaves per plant and the number of branches per plant were counted from the same plants at the aforementioned stages to evaluate vegetative growth. After attaining physiological maturity, the yield parameters like grain yield (q/ha) and straw yield (q/ha) were recorded from the net plot area and computed on to per-hectare basis. The harvest index (%) was calculated as the ratio of grain yield to total biological yield multiplied by 100. The oil content (%) of seed samples was estimated using the Soxhlet extraction method as described by **Pearson (1976).**

Statistical Analysis

Data from both years were tested for homogeneity and then pooled for analysis. The combined mean data were subjected to Analysis of Variance (ANOVA) appropriate for RBD as per Gomez and Gomez (1984). Treatment means were compared using the critical difference (CD) at the 5% level of significance (P = 0.05). All statistical analyses were performed using R statistical software.

Results

Growth attributes

The data pertaining to growth attributes like plant height (cm), number of leaves and number of branches was described below.

Plant height

The mean data suggest that conservation agriculture practices combined with organic nutrient sources increased the plant height of mustard at all growth stages. The treatment T (No-till + Egg amino acid @ 1 L/ha + Poultry manure @ 4 t/ha) resulted in the highest plant height of 36.91, 106.28, 166.91 and 183.91 cm at 30, 60, 90 DAS and at harvest, respectively.

In contrast, the lowest plant height of 19.21, 78.43, 136.93, and 154.08 cm was obtained under T (Control). At 30 DAS, treatments T and T were found to be statistically equivalent to T, demonstrating an early optimistic response to no-tillage combined with organic amendments. Correspondingly, at 60 and 90 DAS, the treatments T, T, T, and T revealed statistical parity with T, portentously continued vegetative growth under residue retention and liquid bio-formulations. At harvest, the treatments T, T, T, T, and T also endured statistically analogous to the maximum (T), reflecting the long-term advantageous outcome of conservation-based organic management on mustard growth.

No. of leaves

The mean data indicated that both factors pointedly prejudiced the number of leaves per plant at all growth stages. The treatment T (No-till + Egg amino acid @ 1 L/ha + Poultry manure @ 4 t/ha) resulted in the maximum number of leaves of 11.05, 25.55, 40.61, and 30.67 at 30, 60, 90 DAS and at harvest, respectively. The minimum leaf count of 8.55, 13.94, 24.72, and 19.00 resulted under the control (T).At 30 DAS, the treatments T, T, T, and T were statistically at par with T. Correspondingly, at 60, 90 DAS and at

Table 1. Treatment combinations of the experiment

S. N.	T. N.	Treatment combination
1	T_1	Control
2	T_2	RDF (60:60:40)
3	T_3	Intercropping with Legumes (IC)
4	T_4	Crop residue (CR)+ panchgavya (PG) – 4L/ha + Poultry Manure (PM) – 4t/ha
5	T_5	Crop residue (CR)+ panchgavya (PG) – 4L/ha + Vermicompost (VC) – 8t/ha
6	T_6	Crop residue (CR)+ panchgavya (PG) – 4L/ha + Farmyard Manure (FYM) -12t/ha
7	T_7	No-Till (NT)+ Egg amino acid (EA) -1L/ha + Poultry Manure (PM) – 4t/ha
8	T_8	No-Till (NT)+ Egg amino acid (EA) – 1L/ha + Vermicompost (VC) – 8t/ha
9	T_9	No-Till (NT)+ Egg amino acid (EA) – 1L/ha + Farmyard Manure (FYM) – 12t/ha
10	T_{10}	Mulching (MUL)+Jeevamrith (JA)- 2L/ha+ Poultry Manure (PM) – 4t/ha
11	T_{11}	Mulching (MUL)+Jeevamrith (JA)- 2L/ha +Vermicompost (VC) – 8t/ha
12	T_{12}	Mulching (MUL)+Jeevamrith (JA)- 2L/ha + Farmyard Manure (FYM) – 12t/ha

harvest, the treatments T and T revealed statistical parity with T, signifying that the combined application of no-tillage, egg amino acid and poultry manure or their organic equivalents under residue-based systems endorsed sustained foliage development through the crop growth period.

No. of branches

Similarly, both factors have exerted a significant influence on the number of branches per plant at all growth stages. The treatment T (No-till + Egg amino acid @ 1 L/ha + Poultry manure @ 4 t/ha) resulted in the highest number of branches of 6.60, 13.45, 16.95, and 17.87 at 30, 60, 90 DAS and at harvest, respectively. The lowest number of branches of 3.33, 8.62, 11.95, and 12.89 resulted under the control (T). At 30 DAS, the treatments T, T, and T were statistically at par with T, signifying analogous early branching behaviour. At 60 DAS, the treatments T, T, T, and T upheld statistical parity with T, reflecting sustained vegetative growth under organic and residue-based conditions. At harvest, the treatments T, T, T, T, T, and T were statistically equivalent with T, suggesting that multiple conservation–organic combinations were effective in encouraging branch development.

Yield contributing attributes

Number of siliquae per plant
The number of siliquae per plant differed evidently among treatments. The maximum siliquae per plant (187.20) was obtained under T (No-till + Egg amino acid @ 1 L/ha + Poultry manure @ 4 t/ha), while the minimum (113.23) was obtained under the control (T). The treatments T and T were statistically at par with T, demonstrating that the integration of no-tillage with organic inputs steadily endorsed sophisticated reproductive growth and siliqua formation.

Number of seeds per siliquae

Similarly, the number of seeds per siliqua exhibited a momentous response to the applied treatments. The highest (12.88) seeds per siliqua were recorded under T, followed by treatments T, T, T, T, T, and T, which were statistically equivalent to the highest. The lowest (9.27) seeds per siliqua resulted under T

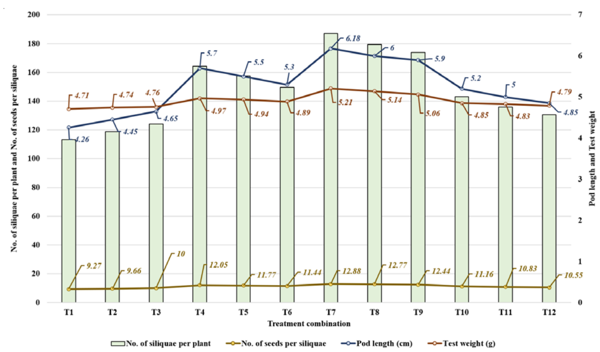

Fig. 1. Effect of conservation agriculture practices and organic sources on the yield contributing attributes of mustard.

Table 2. Effect of conservation agriculture practices and organic sources on the growth attributes of mustard.

	Plant height (cm)				No. of leaves				No. of branches			
	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_1	19.21	78.43	136.93	154.08	8.55	13.94	24.72	19.00	3.33	8.62	11.95	12.89
T_2	19.78	81.71	140.75	158.25	8.66	15.38	27.05	19.44	3.92	9.49	12.99	13.90
T_3	21.58	84.30	138.20	155.35	9.16	16.00	27.39	20.28	4.32	10.13	13.62	14.54
T_4	31.51	101.18	159.28	176.48	10.50	21.38	32.60	26.94	5.70	12.05	15.55	16.47
T_5	29.05	98.78	154.55	171.61	10.05	20.71	34.49	24.61	5.52	11.82	15.32	16.40
T_6	27.48	95.76	151.98	169.03	9.78	20.38	34.16	24.28	5.32	11.35	14.85	15.77
T_7	36.91	106.28	166.91	183.91	11.05	25.55	40.61	30.67	6.60	13.45	16.95	17.87
T_8	35.15	103.63	164.45	181.61	11.05	23.38	38.72	28.67	6.35	13.19	16.69	17.60
T_9	33.71	104.31	161.85	179.01	10.61	23.05	37.16	28.28	5.99	12.69	16.52	17.44
T_{10}	26.35	92.15	149.61	166.78	9.49	19.05	31.16	23.50	4.98	11.12	14.95	15.87
T_{11}	24.66	89.31	146.75	163.91	9.39	18.16	29.38	21.44	4.82	10.72	14.22	15.14
T_{12}	23.38	86.05	143.95	161.11	9.27	17.66	28.27	20.61	4.62	10.52	14.02	14.94
F test	S	S	S	S	S	S	S	S	S	S	S	S
SEm (±)	1.325	2.960	4.700	5.721	0.501	1.018	1.719	1.248	0.275	0.625	0.855	0.812
CD	4.068	8.738	13.874	16.887	1.479	3.005	5.074	3.683	0.810	1.845	2.523	2.396
CV	8.394	5.484	5.382	5.883	8.853	9.015	9.261	9.013	9.273	9.606	9.997	8.932

(control). This enhancement under conservation–organic combinations advocate improved nutrient supply and pollination efficacy, favouring seed setting.

Pod length (cm)

A similar trend of other yield contributing parameters was observed for pod length, which oscillated from the lowest 4.26 cm (T) to the highest 6.18 cm (T). The treatments T, T, and T were found to be statistically equivalent to T.

Test weight (g)

The test weight also revealed momentous distinctions among treatments. The maximum 1000-seed weight (5.21 g) was obtained under T, while the maximum (4.71 g) was obtained in the control (T).

Yield attributes

Grain yield (q/ha)

The results revealed that conservation agriculture practices combined with organic nutrient sources pointedlyincreased the grain yield of mustard. The maximum grain yield (20.53 q/ha) was resulted under T (No-till + Egg amino acid @ 1 L/ha + Poultry manure @ 4 t/ha), whereas the minimum yield (16.04 q/ha) was obtained under the control (T). The treatments T, T, T, T, T, T, T, and T were found to be statistically at par with maximum, i.e., T.

Straw yield (q/ha)

Similar to grain yield, the straw yield of mustard was impacted. The maximum straw yield (47.40 q/ha) was recorded under T (No-till + Egg amino acid @ 1 L/ha + Poultry manure @ 4 t/ha), while the minimum (43.11 q/ha) was obtained under the control (T). The treatments T, T, T, T, T, T, T, and T were found to be statistically at par with T.

Harvest index (%)

The data revealed that conservation agriculture practices and organic nutrient sources had a non-significant impact on the harvest index of mustard. Though the variances among treatments were not statistically significant, the arithmetic variation was pragmatic. The maximum harvest index (30.19%) was obtained under T (No-till + Egg amino acid @ 1 L/ha + Poultry manure @ 4 t/ha), while the minimum (27.08%) was renowned under the control (T).

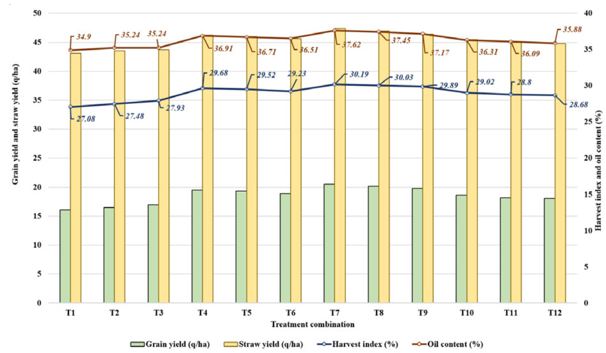

Fig. 2. Effect of conservation agriculture practices and organic sources on the yield and quality attributes of mustard

Quality attributes

Oil content (%)

The mean data specified that conservation agriculture practices combined with organic nutrient sources had a significant influence on the oil content of mustard seed. The maximum oil content (37.62%) was recorded under T (No-till + Egg amino acid @ 1 L/ha + Poultry manure @ 4 t/ha), whereas the minimum (34.90%) was recorded under the control (T). The treatment T was found to be statistically at par with T, signifying that both treatments were correspondingly effective in amplifying oil accumulation.

Discussion

Growth Parameters

Conservation agriculture practices integrated with organic nutrient sources significantly improved the growth performance of mustard, as reflected by increases in plant height, number of leaves, and number of branches. The treatment combining no-tillage, egg amino acid, and poultry manure (T) consistently recorded the highest values across all growth stages. Theimprovement in vegetative growth can be attributed to enhanced soil structure, improved moisture conservation, and higher microbial activity under no-tillage conditions, which favour root development and nutrient uptake. The steady nutrient release from poultry manure and the stimulatory effect of egg amino acids on enzyme activation and hormonal balance further enhanced cell elongation and leaf expansion (Das *et al.*, 2020; Kiboi *et al.*, 2021; Thakur *et al.*, 2023). Similar findings were reported by Dugan *et al.* (2024) and Verma *et al.* (2023), who observed that integrated organic and conservation practices increase canopy development through improved photosynthetic efficiency and delayed senescence. Enhanced branching under these treatments may also be linked to better soil aeration, cytokinin production, and assimilate distribution, resulting in a more vigorous and productive canopy (Chatterjee *et al.*, 2022; Lv *et al.*, 2023). In contrast, the control treatment exhibited lower vegetative growth due to nutrient scarcity and reduced biological activity, leading to restricted root and shoot development (Mondal *et al.*, 2021).

Yield and Yield-Attributing Parameters

Yield and yield-contributing traits such as siliquae per plant, seeds per siliqua, pod length, and test weight were markedly enhanced under conservation–organic combinations. The no-till + egg amino acid + poultry manure (T) treatment consistently recorded the highest values, indicating synergistic benefits of conservation and organic nutrient management. The improvement in reproductive parameters may be attributed to better nutrient synchronisation, improved photosynthetic translocation, and enhanced flower retention and seed set (Tiwari *et al.*, 2023; Narendra *et al.*, 2023). Poultry manure provided a steady supply of nitrogen and phosphorus essential for reproductive development, while bio-stimulants likely improved enzyme activity and assimilate partitioning during pod filling (Kiboi *et al.*, 2021; Meena *et al.*, 2023). Grain and straw yields followed similar trends, with T achieving the highest productivity. These increases resulted from cumulative improvements in vegetative growth, nutrient availability, and soil moisture conservation under no-tillage conditions (Hassan *et al.*, 2023; Gangwar *et al.*, 2023). Enhanced microbial activity and efficient nutrient cycling contributed to better dry matter accumulation and reproductive efficiency (Shilpa *et al.*, 2023; Walia *et al.*, 2024). Although the harvest index differences were statistically non-significant, a marginal increase under T indicates that improved physiological efficiency and assimilate utilization enhanced both grain and biomass yields (Al-Tawarah *et al.*, 2024; Alam *et al.*, 2024).

Quality Parameter (Oil Content)

Oil content was significantly influenced by the combined effects of conservation and organic nutrient management. The maximum oil content recorded under T could be ascribed to improved nutrient supply, especially of nitrogen and sulfur, which are key elements in lipid biosynthesis. The enhanced physiological activity induced by egg amino acids, coupled with better soil moisture conservation under no-tillage, supported efficient carbohydrate translocation and lipid accumulation during the seed-filling stage (Ahlawat *et al.*, 2023; Bhutto *et al.*, 2023; Joshi *et al.*, 2023). Similar findings were reported by Meena *et al.* (2023) and Lv *et al.* (2023), who noted that integrated organic and conservation management systems improve seed quality through balanced nutrition and reduced physiological stress. These results affirm that integrating conservation agriculture with organic nutrient sources not only enhances growth and yield but also sustainably improves mustard oil quality.

Conclusion

The study concluded that the integration of no-tillage with egg amino acid (1 L/ha) and poultry manure (4 t/ha) (T) was the most effective practice for enhancing mustard growth, yield, and oil quality. This treatment consistently produced the highest plant height, leaf number, branching, siliquae per plant, seeds per siliqua, pod length, test weight, grain and straw yield, as well as oil content. The superior performance can be attributed to improved soil structure, moisture retention, and microbial activity under no-tillage, coupled with steady nutrient supply and physiological stimulation from poultry manure and egg amino acids. These factors collectively enhanced vegetative growth, reproductive efficiency, and lipid biosynthesis, resulting in higher productivity and quality. The findings demonstrate that T provides a sustainable and efficient approach for mustard cultivation, optimizing both yield and seed oil content while supporting eco-friendly nutrient management.

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Conflict of Interest

The authors declare that there is no conflict of interest among the authors regarding the publication of this research work.

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