



Impact of tillage and nutrient sources on yield characteristics and production of Ethiopian mustard (*Brassica carinata*)

SHILPA¹*, JANARDAN SINGH², SANDEEP MANUJA², POOJA² and RAVEENA³

Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh 176 062, India

Received: 21 June 2022; Accepted: 09 December 2024

ABSTRACT

A field experiment was conducted during winter (*rabi*) seasons of 2019–20 and 2020–21 at the Research Farm of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh to study the impact of tillage and both organic and inorganic fertilizer sources on the yield characteristics and yield of mustard (*Brassica carinata* A. Braun). The experiment was conducted in a split-plot design (SPD) consisted of 12 treatments having 3 tillage practices [zero tillage (ZT); reduced tillage (RT); and conventional tillage (CT)] in main plots along with 4 nutrient sources [75% and 100% of the recommended dose of nitrogen (RDN) applied through farmyard manure (FYM) and 75% and 100% of the recommended dose of fertilizer (RDF)] in sub-plots. Reduced tillage resulted in a noticeably higher count of primary (5.32 and 4.75) and secondary branches/plant (13.52 and 11.00), siliquae/plant (127.1 and 102.3), seeds/silique (11.63 and 9.83), seed yield (1134.6 and 955.4 kg/ha), straw yield (3415.2 and 2810.1 kg/ha), biological yield (4549.8 and 3765.5 kg/ha), production efficiency (6.75 and 5.62 kg/ha/day), and monetary efficiency (0.71 and 0.48) of mustard, which was comparable to conventional tillage (CT). Among various nutrient sources, the application of 100% RDF resulted in a significantly greater number of yield attributes and overall yield of mustard, comparable to that of 75% RDF. Correlation analyses indicated that factors such as the number of primary and secondary branches, siliquae/plant, seeds/silique, test weight, and final plant stand exhibited a positive and significant relationship with mustard yield. It was concluded that among the different tillage practices, reduced tillage (RT) was found to be most effective for enhancing mustard yield, while with respect to nutrient sources, 100% RDF proved to be superior. The interaction effects of the various treatments were found to be non-significant over both the years of study.

Keywords: Farmyard manure, Fertilizer, Mustard, Tillage, Yield

Oilseed crops rank as the second most significant factor in the agricultural economy, following cereals among field crops. Among nine oilseed crops of India, soybean and mustard (*Brassica carinata* A. Braun) contribute about 44% and 24% area and 38% and 27% of the total oilseed production on average from 2016–17 to 2020–21 (Anonymous 2024). The growing of oilseed crops, in general, requires minimal labour, making them suitable for areas with a shortage of workers. Mustard is a widely cultivated *rabi* oilseed crop in India, with its oil used for household purposes and the oil cake utilized as animal feed and fertilizer (Singh *et al.* 2014). Among the rapeseed and mustard varieties, Karan rai has a high yield, demonstrates better adaptability to environmental conditions, and showed

considerable resistance to pests and diseases (Sekhawat *et al.* 2012). However, traditional tillage practices have been employed for the cultivation of various crops for a long time, but they are now viewed as costly operations regarding labour and fuel use, in addition to contributing to significant erosion. Researchers and farmers are exploring alternative tillage approaches due to concerns about the environment and associated costs. A great deal of focus has been directed towards conservation tillage techniques, such as reduced tillage or no-till farming, as these systems preserve more crop residues and provide better control against erosion (Katiyar 2001). On the other hand, fertilization is widely recognized as a way of improving crop production efficiency and sustainability.

Conversely, fertilization is well acknowledged as a method to enhance agricultural production efficiency and sustainability. Inorganic and organic nutrient sources can potentially rectify the declining trend in soil health and production efficiency by addressing marginal deficiencies of certain secondary and micronutrients, as well as enhancing the microflora and fauna, thereby positively influencing the

¹Lovely Professional University, Phagwara, Punjab;
²Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh; ³R N B Global University, Bikaner, Rajasthan. *Corresponding author email: manhasshilpa8@gmail.com

physical and biological properties of soil (Chondie 2015, Shilpa *et al.* 2023). Determining the optimal tillage method that maximizes measurable residue retention and soil fertility to improve crop output can enable farmers to achieve greater profitability with reduced input requirements (Stagnari *et al.* 2017). The study aimed to evaluate various tillage practices and assess the effects of crop mulch retention under reduced tillage, along with different nutrient sources, on mustard yield and yield attributes. The findings from this research can provide valuable insights for the adoption of suitable crops in similar agro-climatic conditions and soil types.

MATERIALS AND METHODS

A field experiment was conducted during winter (*rabi*) seasons of 2019–20 and 2020–21 at the research farm of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur (32° 11' N, 76° 32' E and an elevation of 1290 m amsl), Himachal Pradesh. The soil texture of the experimental field was silty-clay loam being acidic in reaction (pH 5.4), medium in available nitrogen (365.43 kg/ha), available phosphorus (16.37 kg/ha) and available potassium (230.48 kg/ha) with high organic carbon content (8.1 g/kg). The weather conditions are depicted in Supplementary Table 1.

The experiment was conducted in split plot design (SPD) with 12 treatment combinations included 3 tillage practices, viz. zero tillage (ZT), reduced tillage (RT) and conventional tillage (CT) in main plots and 4 organic and inorganic nutrient sources (75 and 100% RDN through FYM and 75 and 100% RDF) in sub plots.

Tillage cultivation measures: Reduced tillage (RT)-with residue (@3 t/ha), Before planting the crop, only primary tillage was given, and the soil was amended with around 30% residue of the previous crop; Conventional tillage (CT), Prior to sowing, optimal tilth in the field was achieved using both primary and secondary tillage; Zero tillage (ZT), After the previous crop was harvested, a non-selective herbicide was applied to kill the weeds. A zero-till precision seed drill was then used to sow the subsequent crop.

Jayanti cultivar was sown at 30 cm row to row spacing on 14th November 2019 and 11th November 2020, respectively. Paraquat @0.6 litre/ha in 750 litre of water was sprayed a week before sowing of the crop. Farmyard manure (FYM) was applied as per treatment. Recommended dose of fertilizers (60:40:40) was applied @75 and 100% at the time of sowing through urea, single superphosphate and muriate of potash, respectively. Soybean straw @3 t/ha was used as mulch material in reduced tillage plots. For weed management, pendimethalin @1.5 kg/ha in 750 litre of water was sprayed just after sowing of the crop. In addition, one hand weeding was also done at 6 weeks after sowing. Other packages of practices, recommended for the region were also followed (Package of practices *rabi*, 2019).

Data was recorded on final plant stand/m², branches/plant, number of siliquae/plant, seeds/siliqua and test weight (Shilpa 2022). Seed yield was recorded on net plot basis and then converted into kg/ha.

Statistical analysis: The data generated from field were subjected to analysis of variance with mean comparison of 5% level of significance (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Effect of tillage, organic and inorganic nutrient sources on yield attributes: RT practices recorded significantly higher primary branches/plant and secondary branches/plant (5.32 and 13.52 and 4.75 and 11 during 2019–20 and 2020–21, respectively) and was at par with conventional practices (Table 1). This rise might be due to moisture conservation under RT which helps the plant to attain the different developmental stages without facing stress. Findings were supported by Singh *et al.* (2014). ZT recorded significantly lower number of primary and secondary branches/plant (4.39 and 11.57 and 3.50 and 9.14 during 2019–20 and 2020–21, respectively). This might be due to soil compaction which did not provide proper moisture for plant's growth and development. Among different nutrient sources, mean significant difference was found. Significantly more primary and secondary branches/plant (6.00 and 13.65 and 4.76 and 11.20 during 2019–20 and 2020–21, respectively) were recorded with 100% RDF which was at par with 75% RDF. This could be owing to better plant establishment in these treatments compared to the other treatments, as well as improved nutrient availability, notably in the case of NPK. Results were similar with Thaneshwar *et al.* (2017) who found more number of branches with the application of NPKs. Lowest number of branches/plant was found with 100% RDN and 75% RDN through farm yard manure during both the years.

Number of siliquae/plant (127.1 and 102.3) were significantly higher under reduced tillage which was at par with conventional tillage (Table 2). This might be due to soybean straw retention as mulch on the soil surface in RT which helped to conserve soil moisture, control weeds, and increase the population of micro flora. Gupta *et al.* (2011) observed that mulch under RT treatment allowed the crop to compete with crops sown on CT and ZT, increasing crop yield by increasing yield attributing characters. Organic and inorganic sources of nutrient significantly affected the number of siliquae/plant. Significantly higher number of siliquae/plant (137.4) was recorded with 100% RDF which was at par (129.0) with 75% RDF during 2019–20. Whereas, during 2020–21, 100% RDF recorded significantly higher number of siliquae/plant (103.1). This might be attributed to overall improvements in vigour, crop growth and development. Since major essential plant nutrients are present in RDF, its incorporation in soil promotes rapid vegetative growth and branching, thereby escalating the sink size in terms of flowering, fruiting and seed setting. The improved overall growth and profused branching owing to 100% RDF application coupled with transport of photosynthates towards reproductive structures, might have increased the yield attributes (Kumar *et al.* 2017).

Seeds/siliqua (11.63) were significantly higher under RT which was at par with conventional tillage (10.80) which

Table 1 Effect of tillage and nutrient sources on yield attributes of Ethiopian mustard

Tillage practices	Primary branches/ plant		Secondary branches/plant		Siliquae/ plant		Seeds/ siliqua		Test weight (g)	
	2019–20	2020–21	2019–20	2020–21	2019–20	2020–21	2019–20	2020–21	2019–20	2020–21
ZT	4.39	3.50	11.57	9.14	107.0	74.8	9.49	8.27	4.43	4.26
RT	5.32	4.75	13.52	11.00	127.1	102.3	11.63	9.83	4.53	4.46
CT	4.99	4.22	13.02	10.15	121.5	95.3	10.80	9.24	4.47	4.35
SEm ±	0.10	0.11	0.22	0.240	2.0	2.2	0.18	0.19	0.05	0.09
LSD ($P=0.05$)	0.38	0.43	0.85	0.94	7.7	8.7	0.69	0.76	NS	NS
Nutrient sources										
75% RDN (FYM)	3.94	3.59	11.88	9.04	99.9	76.6	9.09	7.88	4.35	4.22
100% RDN (FYM)	4.39	3.73	12.08	9.50	107.8	87.8	10.01	8.70	4.39	4.33
75% RDF (Inorganic)	5.28	4.55	13.19	10.65	129.0	95.5	11.38	9.63	4.59	4.40
100% RDF (Inorganic)	6.00	4.76	13.65	11.20	137.4	103.1	12.08	10.25	4.58	4.49
SEm ±	0.12	0.13	0.26	0.322	3.2	2.5	0.30	0.25	0.09	0.07
LSD ($P=0.05$)	0.37	0.37	0.78	0.96	9.5	7.5	0.89	0.73	NS	NS

ZT, Zero tillage; RT, Reduced tillage; CT, Conventional tillage, RDN, Recommended dose of nitrogen; RDF, Recommended dose of fertilizer.

in turn remained at par with ZT (9.49) during 2019–20. Whereas during 2020–21, RT recorded significantly higher number of seeds/siliqua (9.83) which was at par with conventional tillage (9.24). Different nutrient sources i.e. organic and inorganic, significantly affected the number of seeds/siliqua of mustard. Significantly higher number of seeds/siliqua (12.08 and 10.25 during 2019–20 and 2020–21, respectively) were recorded with 100% RDF which

was at par with 75% RDF (11.38 and 9.63 during 2019–20 and 2020–21, respectively). This might be due to balanced dose of fertilizers enhanced the uptake of nutrients, which helped in seed filling. The assimilation of carbohydrates is improved and the siliqua size is increased as a result of NPK fertilization. The increased metabolic activity that results from the effective utilization of phosphorus in the presence of nitrogen may be the reason for improved seed

Table 2 Effect of tillage and nutrient sources on yield of Ethiopian mustard

Treatment	Seed yield (kg/ha)		Straw yield (kg/ha)		Biological yield (kg/ha)		Production efficiency (kg/ha/day)		Harvest index (%)		Monetary efficiency	
	2019– 20	2020– 21	2019– 20	2020– 21	2019– 20	2020– 21	2019– 20	2020– 21	2019– 20	2020– 21	2019– 20	2020– 21
<i>Tillage practices</i>												
ZT	966.0	825.4	2950.9	2464.6	3916.9	3290.0	5.75	4.86	24.7	25.1	0.62	0.42
RT	1134.6	955.4	3415.2	2810.1	4549.8	3765.5	6.75	5.62	25.0	25.3	0.71	0.48
CT	1072.0	907.8	3240.4	2708.9	4312.4	3616.7	6.38	5.34	24.9	25.1	0.55	0.35
SEm ±	24.4	17.4	73.3	61.8	87.1	64.3	0.15	0.10	0.8	0.5	-	-
LSD ($P=0.05$)	95.7	68.1	287.7	242.6	341.9	252.3	0.57	0.40	NS	NS	-	-
<i>Nutrient sources</i>												
75% RDN (FYM)	939.4	761.7	2842.1	2318.7	3781.5	3079.4	5.59	4.47	24.9	24.7	0.40	0.17
100% RDN (FYM)	989.4	824.1	3053.6	2521.1	4043.0	3345.3	5.89	4.85	24.6	24.7	0.39	0.20
75% RDF (Inorganic)	1130.3	974.1	3408.8	2824.7	4539.1	3798.7	6.73	5.73	25.0	25.6	0.85	0.64
100% RDF (Inorganic)	1171.0	1025.9	3504.2	2980.3	4675.2	4006.2	6.97	6.03	25.0	25.6	0.86	0.67
SEm ±	36.0	30.5	113.5	80.6	107.0	96.4	0.21	0.18	0.7	0.7	-	-
LSD ($P=0.05$)	107.0	90.6	337.2	239.3	318.0	286.6	0.64	0.53	NS	NS	-	-

ZT, Zero tillage; RT, Reduced tillage; CT, Conventional tillage, RDN, Recommended dose of nitrogen; RDF, Recommended dose of fertilizer.

filling, which in turn leads to an increase in fill percentage. Khakwani *et al.* (2014) also reported that the number of seeds/siliqua increased as the intensity of fertilization increased. Test weight remained non - affected with different tillage practices and nutrient sources. Results were similar with Banjara *et al.* (2017) who found that test weight did not differ significantly due to tillage practices. Although, residual effects from the previous legume crop (soybean) resulted in increased test weight (Choudhary *et al.* 2020). Among different nutrient sources, 100% RDF recorded the highest test weight during both the years. The seed size must have increased due to more carbohydrates, synthesis process, and other factors under integrated nutrition supply by the plant because it had higher vegetative growth due to better root development and favourable moisture conditions. Interaction effect among different treatments remained non-significant for different yield attributes during both the years.

Effect of tillage, organic and inorganic nutrient sources on yield: Seed yield and straw yield was significantly affected by tillage practices, organic and inorganic sources of nutrients during both the years. RT resulted in higher seed yield which was at par with conventional tillage during 2019–20 and 2020–21, respectively. RT showed 17.45% and 15.75% increase in seed yield and 15.73% and 9.81% increase in straw yield than ZT. Increased production under reduced tillage was aided by higher nutrient bioavailability from preceding crops along with adequate soil moisture under retained residues. Results were relatable with Abdallah *et al.* (2021) who confirmed that annual weeds were suppressed to a greater extent by legume cover crop residues. Mineralization is aided by the addition of plant wastes with a low C/N ratio, which makes nutrients available to plants. Retained soybean residues in RT treatments, on the other hand, boosted and prolonged soil moisture conservation, favoured improved development with higher photosynthetic efficiency, resulting in improved yield attributes and higher crop yields. Results were similar with Faiz *et al.* (2022). The reduced output in 2020–21 may be attributed to irregular and inadequate effective rainfall, which adversely impacts germination and overall mustard performance. RT resulted in significantly higher biological yield which was at par with conventional tillage. An ideal crop rotation, which should include legume, is one of the

most important variables impacting the maintenance of soil fertility and production. It boosts crop output while reducing workload and reducing negative environmental effect (Ventor *et al.* 2016). The ZT without residue treatments having lower grain, stover and biological yields than RT plots highlighted the need of residue for higher yield (Roy *et al.* 2023). Among different nutrient sources, significantly higher seed, straw and biological yield was recorded with 100% recommended dose of fertilizers which was at par with 75% recommended dose of fertilizers during both the years (Table 2). This could be due to the reason that residual benefit of previously harvested soybean was additive with application of inorganic fertilizer, which provided efficient use of nitrogen and thus gave an increase in yield of mustard. Rotation with legume crops provided other benefits, such as escalating the content of organic matter in the soil, lowering weed density, reducing the spread of diseases, and safeguarding the soil in periods between main crops, in addition to enriching the crop cycle by boosting biodiversity.

Significantly higher production efficiency was recorded under RT which was at par with CT during 2019–20 and 2020–21, respectively. Reduced and conventional tillage recorded 17.39% and 10.96% and 9.88% and 15.64% higher production efficiency than zero tillage, during 2019–20 and 2020–21, respectively. Kocira *et al.* (2020) reported that RT combined with residue retention reduces soil loss while increasing crop production efficiency. Different nutrient sources provided significant results on production efficiency of mustard. Application of 100% RDF recorded significantly higher production efficiency which was at par with 75% RDF during 2019–20 and 2020–21, respectively. Harvest index remained unaffected due to different tillage practices and nutrient sources. Interaction effect among different treatments remained non-significant. In terms of economics, RT recorded higher monetary efficiency followed by ZT. Prabhamani and Babalad (2018) and Manhas *et al.* (2024) recorded increased monetary efficiency in conservation tillage due to reduced fuel burning by reducing tillage intensity. Among nutrient sources, application of 100% RDF recorded higher monetary efficiency followed by 75% RDF.

Interaction effect among different treatments remained non-significant for yield during both the years.

Correlation between yield attributes and yield: Some

Table 3 Correlation matrix between yield attributes and yield of mustard

Mustard parameters	Primary branches	Secondary branches	Siliquae/plants	Seeds/siliqua	Test weight	Final plant stand
Primary branches						
Secondary branches	0.827**					
Siliquae/plants	0.838**	0.812**				
Seeds/siliqua	0.853**	0.791**	0.837**			
Test weight	0.513**	0.523**	0.535**	0.417*		
Final plant stand	0.633**	0.598**	0.542**	0.586**	0.322 ^{NS}	
Seed yield	0.780**	0.745**	0.810**	0.798**	0.578**	0.643**

**Significant at $P \leq 0.01$.

parameters were either positively correlated to others while some were not correlated (Table 3). Yield of mustard was significantly and positively correlated with primary and secondary branches, siliquae/plant, seeds/siliquae and final plant stand. This indicates that a rise in one parameter resulted in an increase in the parameter to which it is significantly connected. Test weight showed no-significant correlation with seed yield. Results were in similarity with Kasu-Bandi *et al.* (2019) which reported positive correlation between growth and yield parameters.

Research findings suggested that transitioning from conventional tillage to reduced tillage is advocated for boosting production efficiency, and enhancing profitability in agricultural endeavors. Additionally, among various nutrient sources, employing 100% of the recommended dose of fertilizers demonstrates superior results in terms of both agronomical outcomes and economic viability.

REFERENCES

- Abdallah A M, Jat H S, Choudhary M, Abdelaty E F, Sharma P C and Jat M L. 2021. Conservation agriculture effects on soil water holding capacity and water saving varied with management practices and agro-ecological conditions: A review. *Agronomy* **11**(1681): 1–19.
- Anonymous. 2024. <https://www.rroij.com/open-access/dynamics-of-oilseeds-in-india-an-overview.php?aid=89823> dated 21th, 2024.
- Banjara T R, Pali G P, Kumar B and Kumar S. 2017. Tillage practices influence on growth, yield and economics of Toria (*Brassica rapa* var. Toria) under rainfed condition of Chhattisgarh. *Journal of Oilseed Brassica* **8**(2): 163–67.
- Chondie Y G. 2015. Effect of integrated nutrient management on wheat. *Journal of Biology, Agriculture and Health Care* **5**(13): 68–76.
- Choudhary A K, Bana R S, Pooniya V, Dass A and Varatharajan T. 2020. Integrated crop management technology for enhanced production efficiency, resource-use efficiency and soil health in legumes-A review. *The Indian Journal of Agricultural Sciences* **90**: 1839–49.
- Faiz M A, Bana R S, Choudhary A K, Laing A M, Bansal R, Bhatia A, Bana R C, Singh Y V, Kumar V, Bamboriya S D, Padaria R N, Khaswan S L and Dabas J P S. 2022. Zero tillage, residue retention and system-intensification with legumes for enhanced pearl millet production efficiency and mineral biofortification. *Sustainability* **14**(543): 1–19.
- Gomez K A and Gomez A A. 1984. *Statistical Procedure for Agricultural Research*, 2nd edn, pp. 680. Wiley Inter Science, New York, USA.
- Gupta M, Bali A S, Kour S, Bharat R and Bazaya B R. 2011. Effect of tillage and nutrient management on resource conservation and production efficiency of wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **56**(2): 1–5.
- Kasu-Bandi B T, Kidinda L K, Kasendue G N, Longanza L B, Emery K L and Lubobo A K. 2019. Correlations between growth and yield parameters of soybean [*Glycine max* (L.) Merr.] under the influence of *Bradyrhizobium japonicum* in Kipushi (The Democratic Republic of Congo). *American Journal of Agricultural and Biological Sciences* **14**: 86–94.
- Katiyar S C. 2001. Water use and yield of rainfed mustard as influenced by moisture conservation practices. *Indian Journal of Soil Conservation* **29**(2): 182–83.
- Khakwani A A, Noor S, Sadiq M, Awan I U, Munir M, Ghazanfarullah M B and Bakhsh I. 2014. Impact of plant densities and NPK fertilization on growth and optimum economic return of sunflower. *Sarhad Journal of Agriculture* **30**(2): 157–64.
- Kocira A, Staniak M, Tomaszewska M, Kornas R, Cymerman J, Panasiewicz K and Lipinska H. 2020. Legume cover crops as one of the elements of strategic weed management and soil quality improvement: A review. *Agriculture* **10**(394): 1–41.
- Kumar A, Mahapatra B S, Yadav A, Kumari U, Singh S P and Verma G. 2017. Effect of different fertility levels on growth, yield attributes, yield and quality of Indian mustard (*Brassica juncea* L.). *Annals of Agricultural Research* **38**(1): 98–103.
- Manhas S, Singh J, Manuja S, Saini A, Kumawat R, Dahiya P, Mehta S, Sahoo C, Johnson R, Puthur R T and Fayeizadeh M R. 2024. Assessing the impact of tillage practices and nutrient levels on the growth and productivity of Ethiopian mustard (*Brassica carinata* L.)-soybean [*Glycine max* (L.) Merr.] cropping system. *BMC Plant Biology* **24**: 1059.
- Package of Practices, rabi 2019, pp. 21–25. Choudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Palampur, Himachal Pradesh.
- Prabhamani P S and Babalad H B. 2018. Effect of conservation tillage and nutrient management practices on system production efficiency and economics of different crops under rainfed conditions of Karnataka. *Journal of Farm Sciences* **31**(3): 284–88.
- Roy A, Das T K, Daas A, Bhattacharyya R, Bhatia A, Maity P P, Sudhishri S, Raj R, G Prabhu, Sen S, Rath N, Sharma T and Saha P. 2023. Conservation agriculture, nitrogen and residual sulphur effects on maize (*Zea mays*) growth and yield in a long-term maize-Indian mustard (*Brassica juncea*) system. *The Indian Journal of Agricultural Sciences* **93**(12): 1362–66.
- Sekhawat K, Rathore S S, Premi O P, Kandpal B K and Chauhan J S. 2012. Advances in agronomic management of Indian mustard [*Brassica juncea* (L.) Czernj. Cosson]: An overview. *International Journal of Agronomy* **2012**(1): 1–14.
- Shilpa, Singh J, Pooja, Raveena, Parita and Kaur N. 2023. Study on tillage, organic and inorganic nutrient sources: A short-term agronomic and economic analysis of soybean (*Glycine max* L.) under sub humid agro-climatic conditions. *Legume Research*. DOI 10.18805/LR-5099
- Shilpa. 2022. Studies on tillage, organic and inorganic sources of nutrients in Mustard-Soybean cropping system, pp. 72–75. Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Palampur, Himachal Pradesh, India.
- Singh M K, Singh Y K, Meena R A, Kumar P, Rajput B S and Nath T. 2014. Effect of tillage and mulch in mustard crop under rainfed conditions. *International Journal of Tropical Agriculture* **32**(1–2): 251–54.
- Stagnari F, Maggio A, Galieni A and Pisante M. 2017. Multiple benefits of legumes for agriculture sustainability: An overview. *Chemical and Biological Technologies in Agriculture* **4**: 2. DOI: 10.1186/s40538-016-0085-1
- Thaneshwar, Singh V, Prakash J, Kumar M, Kumar S and Singh R K. 2017. Effect of integrated nutrient management on growth and yield of mustard (*Brassica juncea* L.) in irrigated condition of up/Gangetic Plain Zone of India. *International Journal of Current Microbiology and Applied Sciences* **6**(1): 922–32.
- Ventor Z S, Jacobs C and Hawkins H J. 2016. The impact of crop rotation on soil microbial diversity: A meta-analysis. *Pedobiology: Journal of Soil Ecology* **59**: 215–22.