International Journal of Bio-resource and Stress Management https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM August 2026, 17(8): 01-08

Article AR7115

Research Article

Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2026.7115

Performance of Different Root Vegetables in Mustard-based Intercropping Systems: Effects on Weed, Nutrient Dynamics and Yield

K. Ramakrishna[1], Ch. Pragathi Kumari[1], Sreedhar Chauhan[1], T. Ram Prakash[2], Kavya Inuganti[1], S. Vijay Kumar[1] and G. M. Imran[3]

[1]Dept. of Agronomy, [2]Dept. of Soil Science and Agricultural Chemistry, Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad, Telangana (500 030), India
[3]Dept. of Agronomy, Navsari Agricultural University, Navsari, Gujarat (396 450), India

Open Access

Corresponding palavaikrishna@gmail.com

0009-0009-5768-3184

ABSTRACT

The experiment was conducted during *rabi* (November-March) 2022 at Agricultural Research Station, Adilabad, Telangana, India to evaluate the effect of mustard-based intercropping with root vegetables on weed dynamics and nutrient uptake. The study was laid out in a randomized block design with 13 treatments comprising sole crops of mustard, radish, beetroot, carrot and potato, along with intercropping systems in 2:2 and 3:3 row ratios. Results revealed that intercropping significantly reduced weed density and dry matter compared to sole cropping. Among treatments, mustard+radish (3:3) recorded the lowest weed density (3.90 and 5.93 m^{-2}), dry weight (12.10 and 24.12 g m^{-2}) along with the highest weed smothering efficiency (25.18% and 29.05%) at 30 and 60 DAS, respectively which resulted in higher mustard equivalent yield (3964 kg ha^{-1}). This combination was even effective at 2:2 ratio. Nutrient uptake varied significantly among treatments, with mustard+potato (3:3) recording the highest total nitrogen uptake (90.97 kg ha^{-1}), while mustard + carrot (3:3) recorded maximum phosphorus (30.86 kg ha^{-1}) and potassium uptake (146.31 kg ha^{-1}). Intercropping systems showed higher total nutrient uptake than sole mustard, indicating improved resource use efficiency due to complementary interactions between component crops. However, the available soil N, P and K status at harvest remained non-significant across treatments. mustard-based intercropping with root vegetables, particularly in a 3:3 row ratio, proved effective for weed suppression and enhanced nutrient utilization, in particular mustard+radish at 2:2 and 3:3 combination be considered as a sustainable approach for improving productivity and resource efficiency in cropping systems.

KEYWORDS: Mustard, intercropping, radish, carrot, potato, weeds, nutrients, efficiency

Citation* (VANCOUVER)*: Ramakrishna et al., Performance of Different Root Vegetables in Mustard-based Intercropping Systems: Effects on Weed, Nutrient Dynamics and Yield. *International Journal of Bio-resource and Stress Management,* 2026; 17(8), 01-08. HTTPS://DOI.ORG/10.23910/1.2026.7115.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, author have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The author has declared that no conflict of interest exists.

RECEIVED on 07th April 2026 RECEIVED in revised form on 10th July 2026 ACCEPTED in final form on 28th July 2026 PUBLISHED on 07th August 2026

1. INTRODUCTION

Mustard (*Brassica juncea* L.) is one of the most important oilseed crops grown during the *rabi* season under both irrigated and rainfed conditions in India. It plays a vital role in meeting the country's edible oil requirements and contributes significantly to the agricultural economy. Globally, India ranks second in area and third in production, with 6.85 mha under cultivation, producing 9.12 mt with an average productivity of 1331 kg ha^{-1} (Anonymous, 2022). In Telangana region, mustard cultivation has expanded to approximately 3000 ha with a production of 5000 t in recent 4-5 years (Anonymous, 2021). However, its productivity remains comparatively low due to various agronomic and ecological constraints. The continuous cultivation of a limited number of crops under monocropping systems has led to short-term yield gains but has adversely affected long-term sustainability with depletion of soil fertility, declining groundwater levels, increased weed infestation and higher incidence of pests and diseases (Karthik et al., 2023). Continuous cultivation of a single crop also reduces biodiversity and disrupts ecological balance, ultimately affecting system sustainability and profitability (Tilman et al., 2002; Foley et al., 2011). In India, intensive cropping has further contributed to declining factor productivity and reduced farm income (Bhattacharyya et al., 2015). These limitations necessitate the exploration of alternative cropping strategies that can improve productivity without compromising environmental health. Crop diversification, particularly through intercropping, has emerged as an effective approach to address these issues. Intercropping enables better utilization of resources such as light, water and nutrients (Lin, 2011). It enhances system productivity, improves soil health and contributes to resilience under changing climatic conditions (Brooker et al., 2015; Zhang et al., 2015). The success of intercropping systems largely depends on the selection of compatible crops and appropriate spatial arrangements that reduce interspecific competition while promoting complementary interactions (Hauggaard-Nielsen et al., 2001; Tiwari et al., 2021). Mustard-based intercropping systems have shown promising potential due to the crop's adaptability and growth characteristics (Kumari et al., 2023; Singh et al., 2023). Integrating mustard with root vegetables such as carrot (*Daucus carota*), radish (*Raphanus sativus*), beetroot (*Beta vulgaris*) and potato (*Solanum tuberosum*) offers distinct advantages due to difference in canopy structure, rooting depth and nutrient uptake patterns, which allows for efficient resource sharing and reduced competition (Akchaya et al., 2025). Root vegetables, being short-duration and high-value crops, also contribute to increased economic returns and improved land use efficiency. Weed management remains a major challenge in mustard cultivation, as weeds compete aggressively for nutrients, moisture and light, leading to significant yield losses. Intercropping can play a crucial role in suppressing weed growth through shading effect and enhanced crop competition (Neupane et al., 2021; Singh et al., 2025). Certain intercrops can effectively occupy ecological niches, thereby limiting weed emergence and growth (Bhanu et al., 2019; Kaur et al., 2016). In addition to weed suppression, nutrient dynamics are a critical aspect influencing the sustainability of cropping systems. Intercropping systems often exhibit improved nutrient use efficiency due to complementary interactions between component crops, such as differences in root distribution and nutrient acquisition strategies (Kour et al., 2013; Romaneckas et al., 2020). This can result in higher total nutrient uptake compared to sole cropping systems. Spatial arrangement, particularly row ratio, plays a key role in determining the performance of intercropping systems. Proper plant geometry ensures optimal use of available resources and minimizes competition between crops (Tiwari et al., 2021; Devi et al., 2014). Considering these aspects, the present study was undertaken with an objective to identify an efficient and sustainable cropping system that can suppress weeds, enhance nutrient utilization and improve overall productivity without adversely affecting soil fertility.

2. MATERIALS AND METHODS

2.1. Study site and soil characteristics

A field experiment was conducted at Agricultural Research Station, Adilabad, Telangana during *rabi*, 2022 in black soil with neutral pH (7.35), having EC of 0.19 dS m^{-1}, medium in organic carbon (0.67%) and low in available nitrogen (100.8 kg ha^{-1}), medium in phosphorus (47.4 kg ha^{-1}) and high in potassium (426 kg ha^{-1}).

2.2. Experiment design and treatments

The experiment was laid out in randomized block design with 13 treatments namely, T_1: Sole mustard; T_2: Sole radish; T_3: Sole beetroot; T_4: Sole carrot; T_5: Sole potato; T_6: Mustard+radish (2:2); T_7: Mustard+beetroot (2:2); T_8: Mustard+carrot (2:2); T_9: Mustard+potato (2:2); T_{10}: mustard+radish (3:3); T_{11}: Mustard+beetroot (3:3); T_{12}: mustard+carrot (3:3); T_{13}: Mustard+potato (3:3), replicated thrice.

2.3. Observations

2.3.1. Weed parameters

Weed count and weed dry weight were taken in each treatment plot by using a 1 m^2 (1.0×1.0 m^2) quadrant and the mean value was taken as weed density per 1.0 m^2. The total number of weeds and weed dry weight was recorded at 30 and 60 DAS stages of the crop. Thus, weed density and dry weight were statistically subjected to square root transformation for normalising the data.

$X=\sqrt{(N+1)}$

Where X-transformed weed value and N-actual weed value.

2.3.2. Weed smothering efficiency (%)

Weed smothering efficiency is an appropriate index to measure the efficacy of weed control, which indicates the comparative magnitude of reduction in weed dry matter and was highly influenced by different intercropping systems.

$WSE=\{(DW_m-DW_i)/DW_m\}\times100$

Where,

DW_m is the mean dry weight of weeds in a pure crop plot (g m^{-2}) and

DW_i is the mean dry weight of weeds in the intercropped plot (g m^{-2}).

2.3.3. Soil and plant analysis

The pH of soil was determined in a 1:2.5 soil-to-water suspension after stirring the samples intermittently for half an hour using a pH meter (Jackson, 1973). The electrical conductivity of soil was determined in the supernatant of a 1:2.5 soil to water suspension that was used for pH estimation by using a Systronics direct digital conductivity meter-304 (Jackson, 1973). The organic carbon content was estimated by wet digestion method as per the procedure adopted by Walkley and Black (1934). Available nitrogen in the soil was estimated by the alkaline permanganate method (Subbaiah and Asija, 1956). Available phosphorus in the soil sample was extracted with Olsen's reagent (Olsen et al., 1954). Available potassium was determined by extracting the soil with neutral normal ammonium acetate solution and estimated using flame photometer method as outlined by Jackson (1973).

2.3.4. Nutrient uptake studies

Powdered plant samples, viz., crop (seed and stalk), were separately treated with concentrated sulphuric acid overnight for pre-digestion for nitrogen estimation using diacid mixture (HNO_3:$HClO_4$ in 9:4) and triacid for phosphorus and potassium estimation. The nitrogen content was estimated by the modified Micro Kjeldahl method by using the Kel-plus instrument, phosphorus by the Vanado-Molybdo phosphoric yellow colour method, and potassium was determined by using a Flame Photometer (Piper, 1966). Nutrient uptake was calculated by the given formula,

Nutrient uptake (kg ha^{-1})={(Total dry weight (kg ha^{-1})× Nutrient content (%)}/100

3. RESULTS AND DISCUSSION

3.1. Weed density (No. m^{-2}) at 30 and 60 DAS

The weed density recorded at 30 and 60 DAS showed significant variation among the different sole and intercropping treatments, with a consistent trend of higher weed infestation in sole crops and reduced weed population under intercropping systems (Table 1). Sole beetroot (6.41 and 8.60) and sole potato (6.01 and 8.67) recorded maximum weed density at both stages. Followed by sole mustard (5.39 and 7.69), radish (5.38 and 7.50) and carrot (5.48 and 8.20) also maintained relatively higher weed densities. In contrast, all mustard-based intercropping treatments significantly reduced weed density at both stages. Among them, mustard + radish (3:3) consistently recorded the lowest weed density (3.90 at 30 DAS and 5.93 at 60 DAS), which was significantly superior to all sole cropping systems. This was followed by mustard+radish (2:2) with 4.14 and 6.71 weed density at 30 and 60 DAS, respectively and mustard+potato (3:3) (4.48 and 6.67 at 30 and 60 DAS), which were significantly better than sole crops.

The consistent performance of mustard+radish (3:3) over time is attributed due to radish faster growing nature and it smothered weeds well, leading to a decrease in the number of weeds in it, and similar results were observed by Baumann et al. (2002) and Kaur et al. (2016). Whereas the superiority of the 3:3 row ratio over 2:2 further suggests that higher plant population and closer row arrangement enhance crop competitiveness, leaving fewer ecological niches for weeds to establish (Biswas et al., 2024).

3.2. Weed dry weight (g m^{-2}) at 30 and 60 DAS

Intercropping mustard with root vegetables showed a significant difference in weed dry matter. Sole cropping systems registered relatively higher weed dry matter with beetroot sole crop at 30 and 60 DAS (17.40 and 33.71 g m^{-2}, respectively), and the lowest was recorded in mustard+radish (3:3) in 30 and 60 DAS (12.10 and 24.12 g m^{-2}, respectively). Intercropping with root vegetable crops, especially at a 3:3 row proportion, had reduced the weed density and dry weight in the mustard crop over sole cropping. This might be due to higher competition posed by the intercrops for resources that resulted in lower weed dry weight. Similar results were reported by Choudhary et al. (2014) and Favacho et al. (2017).

3.3. Weed smothering efficiency at 30 and 60 DAS

Weed smothering efficiency showed an increasing trend from 30 to 60 DAS in intercropping treatments compared to sole cropping, indicating the cumulative suppressive effect of crop competition over time (Table 1). Among the different intercropping systems, mustard+radish (3:3) recorded the highest WSE at both stages (25.18% at 30 DAS and 29.05% at 60 DAS), followed by mustard+beetroot (3:3) (19.65% and 19.32%) and mustard+radish (2:2) (19.55% and 23.41%). In contrast, lower WSE was observed in mustard+potato (2:2) (14.29% and 12.31%) and mustard+carrot (2:2) (14.97% and 15.30%). The higher weed smothering efficiency in mustard+radish (3:3) followed by a 2:2 ratio of similar crops

Table 1: Effect of intercropping mustard with root vegetables on weed density, dry weight and weed smothering efficiency at 30 and 60 DAS

Treatments	Weed density (No. m^{-2})		Weed dry weight (g m^{-2})		Weed smothering efficiency (%)	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
T_1: Mustard sole crop	5.39 (29.12)	7.69 (59.20)	3.94 (14.60)	5.67 (31.25)	-	-
T_2: Radish sole crop	5.38 (29.01)	7.50 (55.0)	3.89 (14.21)	5.43 (28.50)	-	-
T_3: Beetroot sole crop	6.41 (41.21)	8.60 (74.00)	4.30 (17.40)	5.89 (33.71)	-	-
T_4: Carrot sole crop	5.48 (30.10)	8.20 (67.25)	4.06 (15.51)	5.67 (31.25)	-	-
T_5: Potato sole crop	6.01 (36.20)	8.67 (75.20)	4.04 (15.40)	5.54 (30.89)	-	-
T_6: Mustard+Radish (2:2)	4.14 (17.14)	6.71 (45.12)	3.65 (12.33)	5.27 (26.83)	19.55	23.41
T_7: Mustard+Beetroot (2:2)	5.02 (25.21)	7.37 (54.40)	3.75 (13.10)	5.21 (26.22)	15.32	15.80
T_8: Mustard+Carrot (2:2)	5.31 (28.23)	7.81 (61.00)	3.67 (12.51)	5.24 (26.54)	14.97	15.30
T_9: Mustard+Potato (2:2)	5.10 (25.00)	7.24 (52.47)	3.77 (13.22)	5.12 (25.23)	14.29	12.31
T_{10}: Mustard+Radish (3:3)	3.90 (15.41)	5.93 (35.23)	3.61 (12.10)	5.01 (24.12)	25.18	29.05
T_{11}: Mustard+Beetroot (3:3)	4.62 (21.36)	6.91 (47.85)	3.66 (12.43)	5.32 (27.32)	19.65	19.32
T_{12}: Mustard+Carrot (3:3)	4.84 (23.45)	7.15 (51.24)	3.63 (12.23)	5.30 (27.30)	17.69	18.91
T_{13}: Mustard+Potato (3:3)	4.48 (20.16)	6.67 (44.50)	3.62 (12.22)	5.30 (27.13)	16.95	18.60
SEm±	0.249	0.399	0.172	0.271	-	-
CD (p=0.05)	0.735	1.179	0.509	0.800	-	-

Original values are given in parenthesis, outside are square root transformed values with $X=\sqrt{(N+1)}$

was mainly due to rapid early growth, dense canopy cover of radish, which reduces light availability and suppresses weed growth. Similar results were obtained by Seran et al. (2009) with radish intercropping.

3.4. Mustard yield and mustard equivalent yield in intercropping

The yield data indicated significant variation among treatments with respect to mustard yield and mustard equivalent yield (MEY). Sole mustard (T_1) recorded a seed yield of 1556 kg ha^{-1}, which was significantly higher than all intercropping treatments, reflecting the absence of interspecific competition. Among the intercropping systems, mustard yield ranged from 746 to 972 kg ha^{-1}, with the highest yield observed in mustard+radish (3:3) (972 kg ha^{-1}), which was statistically at par with mustard+radish (2:2) (950 kg ha^{-1}). The lowest mustard yield was recorded under mustard+potato (2:2) (746 kg ha^{-1}), which was statistically comparable with mustard+potato (3:3) (754 kg ha^{-1}) and mustard+beetroot systems (Table 2).

In terms of system productivity, as reflected by mustard equivalent yield, sole radish (T_2) recorded the highest MEY (5775 kg ha^{-1}), which was significantly superior to all other treatments. Among intercropping treatments, mustard+radish (3:3) produced the highest MEY (3964 kg ha^{-1}) and was at par with mustard+radish (2:2) (3933 kg

Table 2: Effect of intercropping mustard with root vegetables on mustard and mustard equivalent yield

Treatments	Mustard yield (kg ha^{-1})	Mustard equivalent yield (kg ha^{-1})
T_1: Mustard sole crop	1556	1556
T_2: Radish sole crop	-	5775
T_3: Beetroot sole crop	-	4482
T_4: Carrot sole crop	-	4893
T_5: Potato sole crop	-	3937
T_6: Mustard+Radish (2:2)	950	3933
T_7: Mustard+Beetroot (2:2)	758	3200
T_8: Mustard+Carrot (2:2)	844	3386
T_9: Mustard+Potato (2:2)	746	2646
T_{10}: Mustard+Radish (3:3)	972	3964
T_{11}: Mustard+Beetroot (3:3)	768	3218
T_{12}: Mustard+Carrot (3:3)	855	3406
T_{13}: Mustard+Potato (3:3)	754	2729
SEm±	33	161.3
CD (p=0.05)	98	475.9

ha^{-1}). These treatments were significantly superior to all other intercropping combinations. The lowest MEY among intercropping systems was observed in mustard+potato (2:2) (2646 kg ha^{-1}), which remained statistically similar to mustard+potato (3:3) (2729 kg ha^{-1}) but significantly inferior to radish and carrot-based intercropping systems.

There was reduction in mustard yield under intercropping compared to sole cropping that can be attributed to interspecific competition for essential resources. Similar findings have been reported by Singh et al. (2018) in mustard-based intercropping systems, where component crop yields declined due to competition, but overall system productivity improved due to efficient resource utilization. Among the intercropping systems, radish based combinations (both 2:2 and 3:3) recorded higher mustard yield and intercrop yield, which ultimately resulted in superior mustard equivalent yield. The spatial and temporal complementarity between mustard and radish, where the fast-growing radish develops early canopy cover, suppresses weeds, and exploits deeper soil nutrients, thereby reducing direct competition with mustard attributed the higher MEY as earlier reported by Ramakrishna et al. (2023).

3.5. Nutrient uptake of main and intercrops (N, P, K) at harvest

The data on nitrogen (N), phosphorus (P), and potassium (K) uptake by sole and intercropping systems revealed significant variation among treatments (Table 3). Among sole crops, potato recorded the highest nitrogen uptake (129.50 kg ha^{-1}), followed by beetroot (116.10 kg ha^{-1}), whereas mustard showed the lowest uptake (58.01 kg ha^{-1}). Phosphorus uptake was maximum in carrot (40.20 kg ha^{-1}), while potassium uptake was markedly higher in carrot (226.71 kg ha^{-1}), reflecting its greater nutrient demand and extraction capacity.

Among the combinations, mustard+potato (3:3) recorded the highest total nitrogen uptake (90.97 kg ha^{-1}), followed by mustard+beetroot (3:3) (86.59 kg ha^{-1}), which may be attributed to complementary nutrient use and efficient root distribution. Total phosphorus uptake was highest in mustard+carrot (3:3) (30.86 kg ha^{-1}), closely followed by mustard+carrot (2:2) (30.01 kg ha^{-1}), suggesting the strong phosphorus-extracting ability of carrot in association with mustard. Similarly, potassium uptake was significantly higher in mustard+carrot systems, with the maximum recorded in mustard+carrot (3:3) (146.31 kg ha^{-1}), followed by mustard+carrot (2:2) (141.69 kg ha^{-1}), indicating the dominant role of carrot in potassium uptake.

In intercropping systems, total nutrient uptake was generally higher than that of mustard grown alone, indicating better resource use efficiency, as earlier reported by Romaneckas et al. (2020) and Kour et al. (2013). A consistent trend was observed where 3:3 row ratios performed better than 2:2 ratios across most combinations, as evident in mustard+radish, mustard+carrot, and mustard+potato systems, which may be due to higher plant population and improved utilization of growth resources (Devi et al.,

Table 3: Effect of intercropping mustard with root vegetables on nutrient uptake

Treatments	Main crop uptake (kg ha^{-1})			Inter crop uptake (kg ha^{-1})			Total uptake (kg ha^{-1})		
	N	P	K	N	P	K	N	P	K
T_1: Mustard sole crop	58.01	22.85	64.68	-	-	-	58.01	22.85	64.68
T_2: Radish sole crop	80.90	24.71	92.31	-	-	-	80.90	24.71	92.31
T_3: Beetroot sole crop	116.10	23.42	38.80	-	-	-	116.10	23.42	38.80
T_4: Carrot sole crop	67.10	40.20	226.71	-	-	-	67.10	40.20	226.71
T_5: Potato sole crop	129.50	29.31	123.42	-	-	-	129.50	29.31	123.42
T_6: Mustard+Radish (2:2)	32.49	12.49	34.82	39.80	10.71	45.41	72.29	23.20	80.23
T_7: Mustard+Beetroot (2:2)	28.14	10.59	29.51	56.41	11.00	17.60	84.55	21.59	47.11
T_8: Mustard+Carrot (2:2)	27.89	10.91	29.49	32.60	19.10	112.20	60.49	30.01	141.69
T_9: Mustard+Potato (2:2)	25.12	10.12	27.56	63.70	13.51	58.61	88.82	23.63	86.17
T_{10}: Mustard+Radish (3:3)	33.48	13.71	35.70	41.00	12.12	46.60	74.48	25.83	82.30
T_{11}: Mustard+Beetroot (3:3)	28.38	11.27	30.25	58.21	11.60	18.90	86.59	22.87	49.15
T_{12}: Mustard+Carrot (3:3)	28.31	11.06	30.11	33.40	19.80	116.20	61.71	30.86	146.31
T_{13}: Mustard+Potato (3:3)	25.47	10.45	28.24	65.50	14.41	61.21	90.97	24.86	89.45
SEm±	2.17	0.97	2.9	-	-	-	4.1	1.3	4.7
CD (p=0.05)	6.4	2.86	8.5	-	-	-	12.3	3.9	13.8

2014; Kour et al., 2013). Overall, the results demonstrate that intercropping, particularly mustard+potato and mustard+carrot at 3:3 row ratio, enhanced total nutrient uptake compared to sole cropping, owing to better complementarity, efficient nutrient sharing and improved exploitation of soil resources.

3.6. Available N, P and K status (kg ha^{-1}) at initial and harvest

Available nutrient status of soil in intercropping of mustard with different root vegetables were found to be non-significant (Table 4). Available nitrogen at initial (276 kg ha^{-1}) and at final it is ranged from 203 to 232 kg ha^{-1}. Available phosph**o**rus at initial (44.6 kg ha^{-1}) and at final it is ranged from 40.1 to 45.2 kg ha^{-1}. Available potassium at initial 432 kg ha^{-1} and at final it is ranged from 370 to 412 kg ha^{-1}. This indicated that intercropping mustard with root vegetables did not change the soil nutrient dynamics.

Table 4: Effect of intercropping mustard with root vegetables on available nutrient status at harvest

Treatments	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
T_1: Mustard sole crop	220	45.3	412
T_2: Radish sole crop	232	40.1	409
T_3: Beetroot sole crop	206	42.2	406
T_4: Carrot sole crop	221	41.1	378
T_5: Potato sole crop	209	40.2	370
T_6: Mustard+Radish (2:2)	204	40.3	390
T_7: Mustard+ Beetroot (2:2)	219	42.2	412
T_8: Mustard+Carrot (2:2)	216	45.2	398
T_9: Mustard+Potato (2:2)	212	42.1	409
T_{10}: Mustard+Radish (3:3)	217	39.2	380
T_{11}: Mustard+ Beetroot (3:3)	210	42.2	393
T_{12}: Mustard+Carrot (3:3)	214	43.1	386
T_{13}: Mustard+Potato (3:3)	213	42.2	392
SEm±	10.56	2.0	20.03
CD (p=0.05)	NS	NS	NS
Initial	276	47.0	432

4. CONCLUSION

Mustard-based intercropping with root vegetables enhanced weed control and nutrient uptake over sole cropping. The mustard+radish (3:3) system most effectively reduced weed density and recorded higher yield of mustard due to rapid growth and canopy coverage. Mustard+potato (3:3) showed the highest nitrogen uptake, while mustard+carrot (3:3) excelled in phosphorus and potassium uptake. Overall, 3:3 ratio of mustard based vegetable intercropping performed better in terms of weed suppression, nutrient dynamic and yield.

5. REFERENCES

Akchaya, K., Parasuraman, P., Pandian, K., Vijayakumar, S., Thirukumaran, K., Mustaffa, M.R.A.F., Rajpoot, S.K., Choudhary, A.K., 2025. Boosting resource use efficiency, soil fertility, food security, ecosystem services, and climate resilience with legume intercropping: A Review. Frontiers in Sustainable Food Systems 9, 1527256. DOI: https://doi.org/10.3389/fsufs.2025.1527256.

Anonymous, 2021. Government of India Department of Agriculture Cooperation and Farmers Welfare (DA & FW). Available from: www. agricoop.nic.in. Accessed on 15th July, 2023.

Anonymous, 2022. INDIASTAT, 2022. Available from: https://www.indiastat.com. Accessed on 12th June, 2023.

Baumann, D.T., Bastiaans, L., Kropff, M.J., 2002. Intercropping system optimization for yield, quality, and weed suppression combining mechanistic and descriptive models. Agronomy Journal 94(4), 734–742. DOI: https://doi.org/10.2134/agronj2002.7340.

Bhanu, A.N., Srivastava, K., Singh, R.K., 2019. Advances in agronomic management in Indian mustard for Eastern Uttar Pradesh. Acta Scientific Agriculture 3(8), 70–79. DOI: https://doi.org/10.31080/asag.2019.03.0566.

Bhattacharyya, R., Ghosh, B.N., Mishra, P.K., Mandal, B., Rao, C.S., Sarkar, D., Das, K., Anil, K.S., Lalitha, M., Hati, K.M., Franzluebbers, A.J., 2015. Soil degradation in India: Challenges and potential solutions. Sustainability 7(4), 3528–3570. DOI: https://doi.org/10.3390/su7043528.

Biswas, S., Das, R., Jana, K., Puste, A., 2024. Integrated nutrient management on oat+ grasspea intercropping system: an evaluation of system productivity, economics, energetics and carbon footprint. Scientific Reports 14(1), 19414. DOI: https://doi.org/10.1038/s41598-024-66107-9.

Brooker, R.W., Bennett, A.E., Cong, W.F., Daniell, T.J., George, T.S., Hallett, P.D., Hawes, C., Iannetta, P.P., Jones, H.G., Karley, A.J., Li, L., 2015. Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology. New Phytologist 206(1), 107–117. DOI: https://doi.org/10.1111/nph.13132.

Choudhary, S.K., Singh, R.N., Upadhyay, P.K., Singh, R.K., Choudhary, H.R., Vijay, P., 2014. Effect of vegetable intercrops and planting pattern of maize on growth, yield and economics of winter maize (*Zea mays* L.) in Eastern Uttar Pradesh. Environment and Ecology 32(1), 101–105. DOI: https://doi.org/10.13140/RG.2.2.29090.68804.

Devi, K.N., Shamurailatpam, D., Singh, T.B., Athokpam, H.S., Singh, N.B., Singh, N.G., Singh, L.N., Singh, A.D., Chanu, O.P., Singh, S.R., Devi, K.P., 2014. Performance of lentil (*Lens culinaris* M.) and mustard (*Brassica juncea* L.) intercropping under rainfed conditions. Australian Journal of Crop Science 8(2), 284–289. Available from: https://www.cropj.com/devi_8_2_2014_284_289.pdf.

Favacho, F.S., Lima, J.S.S.D., Bezerra, F., Silva, J.N.D., Barros, A.P., 2017. Productive and economic efficiency of carrot intercropped with cowpea-vegetable resulting from green manure and different spatial arrangements1. Revista Ciencia Agronómica 48, 337–346. DOI: https://doi.org/10.5935/1806-6690.20170039.

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M., Mueller, N.D., O'Connell, C., Ray, D.K., West, P.C., Balzer, C., 2011. Solutions for a cultivated planet. Nature 478, 337–342. DOI: https://doi.org/10.1038/nature10452.

Hauggaard-Nielsen, H., Ambus, P., Jensen, E.S., 2001. Interspecific competition, N use and interference with weeds in pea–barley intercropping. Field Crop Research 70, 101–109. DOI: https://doi.org/10.1016/S0378-4290(01)00126-5.

Jackson, M.L., 1973. Soil chemical analysis (2nd Edn.). Prentice Hall of India, New Delhi. Available from: https://www.scirp.org/reference/ReferencesPapers?ReferenceID=1453838.

Karthik, R., Ramana, M.V., Kumari, C.P., Prakash, T.R., Naik, D.S., Yakadri, M., 2023. Evaluation of various cropping systems on soil health in Southern Telangana Zone. In Biological Forum–An International Journal 15(7), 21–26. Available from: https://www.researchtrend.net/bfij/pdf/Evaluation-of-Various-Cropping-Systems-on-Soil-Health-in-Southern-Telangana-Zone-Rayapati-Karthik-4.pdf.

Kaur, N., Bhullar, M.S., Gill, G., 2016. Weed management in sugarcane-canola intercropping systems in northern India. Field Crops Research 188, 1–9. DOI: https://doi.org/10.1016/j.fcr.2016.01.009.

Kour, R., Sharma, B.C., Kumar, A., Kour, P., 2013. Nutrient uptake by chickpea+mustard intercropping system as influenced by weed management. Indian Journal of Weed Science 45(3), 183–188. Available from: https://isws.org.in/IJWSn/File/2013_45_Issue-3_183-188.pdf.

Kumari, C.P., Chauhan, S., Prakash, T.R., 2023. Growth and yield attributes of mustard as influenced by mustard–based vegetable intercropping systems. International Journal of Environment and Climate Change 13(10), 3340–3346. DOI: https://doi.org/10.9734/ijecc/2023/v13i103002.

Lin, B.B., 2011. Resilience in agriculture through crop diversification: adaptive management for environmental change. BioScience 61(3), 183–193. DOI: https://doi.org/10.1525/bio.2011.61.3.4.

Neupane, R., Karn, R., Bhusal, S., Dahal, B., Jha, R.K., 2021. Influence of mixed cropping of cabbage and mustard on weed dynamics and yield of potato (*Solanum tuberosum*). Food and Agri Economics Review 1(2), 64–76. DOI: http://doi.org/10.26480/faer.02.2021.64.76.

Olsen, S.R., Cole, C.V., Watanabe, F.S., Dean. L.A., 1954. Estimation of available phosphorus in soils by extraction with $NaHCO_3$, USDA Cir. U.S. Washington. 939. Available from: https://dn720703.ca.archive.org/0/items/estimationofavai939olse/estimationofavai939olse.pdf.

Piper, C.S., 1966. Soil and plant analysis. Hans Publisher, Bombay. Available from: https://www.scirp.org/reference/referencespapers?referenceid=2430186.

Ramakrishna, K., Kumari, C.P., Chauhan, S., Prakash, T.R., 2023. Growth and yield attributes of mustard as influenced by mustard–based vegetable intercropping systems. International Journal of Environment and Climate Change 13(10), 3340–3346. DOI: https://doi.org/10.9734/ijecc/2023/v13i103002.

Romaneckas, K., Adamaviciene, A., Sarauskis, E., Balandaite, J., 2020. The impact of intercropping on soil fertility and sugar beet productivity. Agronomy 10(9), 1406. DOI: https://doi.org/10.3390/agronomy10091406.

Seran, T.H., Brintha, I., 2009. Biological and economic efficiency of radish (*Raphanus sativus* L.) intercropped with vegetable amaranthus (*Amaranthus tricolor* L.). The Open Horticulture Journal 2(1), 10–25. DOI: https://doi.org/10.2174/1874840600902010017.

Singh, R.K., Umendra Singh, U.S., Ramawater Meena, R.M., 2018. Productivity, compatibility and economics of wheat (*Triticum aestivum*) and Indian mustard (*Brassica juncea*) intercropping as influenced by farmyard manure and fertilizer levels under irrigated conditions. The Indian Journal of Agricultural Sciences

88(4), 530–539. DOI: https://doi.org/10.56093/ijas.v88i4.79098.

Singh, R.S., Pandey, I.B., Choudhary, C.S., Kumar, A., Narayan, A., Kumar, M., 2025. Response of row ratio in mustard (*Brassica juncea* L.)+faba bean (*Vicia faba* L.) intercropping on growth, yield of crops, system productivity, and economics. Legume Research: An International Journal 48(6), 1011–1015. DOI: https://doi.org/10.18805/LR-5000.

Singh, U.K., Gangwar, B., Srivastava, H., 2023. Effect of mustard-based intercropping systems on yield and profitability under organic management in Bundelkhand region. Indian Journal of Ecology 50(3), 627–630. DOI: https://doi.org/10.55362/IJE/2023/3943.

Subbaiah, B.V., Asija, G.L., 1956. A rapid procedure for the estimation of available nitrogen in soils. Current Science 25, 259. Available from: https://www.cabidigitallibrary.org/doi/full/10.5555/19571900070.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., Polasky, S., 2002. Agricultural sustainability and intensive production practices. Nature 418, 671–677. DOI: https://doi.org/10.1038/nature01014.

Tiwari, D., Singh, V., Kumar, M.S.C., 2021. Productivity of chickpea (*Cicer arietinum* L.) and mustard (*Brassica juncea*) intercropping system as influenced by different row ratios and liquid manures. Current Journal of Applied Science and Technology 40(2), 131–143. DOI: https://doi.org/10.9734/cjast/2021/v40i231267.

Walkley, A., Black, I.A., 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science 37(1), 29–38. DOI: https://doi.org/10.1097/00010694-193401000-00003.

Zhang, L.Z., Zhang, S.P., Evers, J.B., van der Werf, W., Spiertz, H., 2015. Resource use efficiency, ecological intensification and sustainability of intercropping systems. Journal of Integrative Agriculture 14(8), 1542–1550. DOI: https://doi.org/10.1016/S2095-3119(15)61039-5.