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Effect of Intercropping Toria with Cowpea on Yield, Green Fodder Production, and Economic Efficiency

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Abstract: ***A field experiment was conducted during the rabi 2024–25 at the Research Farm, School of Agriculture, Lovely Professional University, Phagwara, Punjab, to assess various spacing and row ratio combinations, including sole cropping and intercropping of toria and cowpea in different row arrangements at 30 cm, 45 cm, and 90 cm spacings. The results revealed that intercropping significantly influenced growth attributes such as plant height, number of branches, LAI, and dry matter accumulation in toria, with T7 (toria 90 cm + cowpea 1:3) showing the best vegetative growth. Cowpea growth was also enhanced under wider spacing, particularly in T7 and T6, which recorded the highest plant height, leaf number, and nodulation. Yield-attributing traits such as siliquae per plant, seeds per siliqua, and 1000-seed weight were highest in T5, T6, and T7, yet the maximum seed and stover yields were observed in T8 (Sole Toria 30 cm), followed closely by T1 (toria 30 cm + cowpea 1:1), indicating the benefit of optimal population density. The toria equivalent yield (TEY) and land equivalent ratio (LER), along with quality parameters including oil content, protein content, and yields, were significantly superior in T8 and T1 quality parameters including oil and protein content and yields were significantly superior in T8 and T1, underscoring the impact of better nutrient assimilation. Overall, the study demonstrates that intercropping toria and cowpea in a 1:1 ratio at 30 cm row spacing offers a sustainable approach to enhancing productivity and resource-use efficiency without compromising crop quality.***

Keywords: Intercropping, Land equivalent ratio (LER), Oil and Protein content, Row spacing, Toria Equivalent ratio (TER).

1. Introduction

Cowpea (*Vigna unguiculata L.*), a versatile leguminous crop valued for its high protein content and soil-enriching properties, is increasingly recognized as a vital component in sustainable agriculture. Grown predominantly in warm climates, cowpea serves multiple roles- as a pulse, fodder, green manure, and vegetable—making it an ideal companion in intercropping systems (Alla *et al.*, 2014). Its nitrogen-fixing ability and contribution to organic matter significantly improve soil fertility and productivity, particularly when intercropped with cereals or oilseeds.

Oilseed crops play a cruciall role in India's agricultural economy, with toria (*Brassica campestris L.),* a short-duration winter crop, being a significant contributor. Toria is primarily cultivated in the eastern states such as Assam, Bihar, Odisha and West Bengal, where it serves as a sustainable option in rice-based cropping systems due to its ability to utilize residual soil moisture and nutrients. India ranks third globally in rapeseed production and second in area under cultivation, with rapeseed-mustard accounting for nearly 28.6% of the total oilseed output (Bora *et al.*, 2022). Despite its economic importance, the productivity of toria in certain regions, such as Odisha (422 kg/ha), remains well below the national average (1176 kg/ha), mainly due to suboptimal agronomic practices and soil fertility constraints (Basumotary *et al.*, 2020).

Intercropping, the simultaneous cultivation of two or more crops on the same field, has long been practiced to enhance yield stability, resource use efficiency, and ecological resilience (Altieri *et al.*, 2017). Cereal-legume intercropping, in particular, has demonstrated superior performance in terms of land use efficiency and soil health. It also provides a natural insurance mechanism against crop failure, suppresses weeds, and supports a balanced agro-ecosystem (Belel *et al.*, 2014; Brooker *et al.*, 2015). In the context of climate variability and the need for sustainable intensification, integrating toria with legumes like cowpea offers a promising strategy to improve oilseed productivity while maintaining soil health.

This research aims to evaluate the performance and agronomic potential of toria–cowpea intercropping systems under varied management practices. The study explores how such integration influences yield, soil fertility, and resource utilization, thereby offering insights into sustainable crop production strategies for smallholder farmers in resource-constrained environments

2. Materials and Methods

The field experiment was conducted during *rabi* 2024-25 at Lovely Professional University Phagwara, Punjab which is situated in the Trans-Gangetic plain at an elevation of 252 meters above sea level (31°22′31.81″ N, 75°23′3.02″ E). This region experiences a subtropical climate with hot summers and cool winters. Toria (*Brassica campestris L.*) was grown under favourable conditions, with average maximum and minimum temperatures of 42.23°C and 21.08°C, respectively and a total rainfall of 234mm during the growing season (September-October), which was adequate for crop growth. Meteorological data were obtained from the Agrometeorology Field Station of the university. Prior to sowing, soil samples (0-30 cm depth) were analysed for physicochemical properties. The soil was loamy sand in texture with 63% sand, 8% silt and 26% clay and having a neutral pH of 7.8 electrical conductivity of 0.17dS/m, available nitrogen 224kg/ha, phosphorus 8.36 kg/ha, and potassium 146.3kg/ha. The experiment was laid out in randomised block design by keeping 9 treatments T1= Toria 30cm + Cowpea fodder (1:1), T2= Toria 45cm + Cowpea fodder (1:1), T3=Toria 60cm + Cowpea fodder (1:1), T4=Toria 60cm + Cowpea fodder (1:2), T5=Toria 90cm + Cowpea fodder (1:1), T6=Toria 90cm + Cowpea fodder (1:2), T7=Toria 90cm + Cowpea fodder (1:3), T8=Sole Toria 30 cm, and T9= Sole Cowpea fodder 30cm with 3 replications.

The experimental field was prepared by ploughing twice with a disc harrow followed by two passes with a cultivator and subsequent planking to achieve a fine tilth suitable for the cultivation of both toria (*Brassica campestris L.)* and cowpea (*Vigna unguiculata*). The soil was well-drained and ideal for the growth of both crops. The toria variety TL-17 and cowpea variety CL-367 was sown on 5th September 2024. Toria was sown using a seed rate of 3.75 kg/ha, while cowpea was sown at 30 kg/ha, with seeds placed 3–4 cm deep. Row spacing for toria was maintained as per treatment specifications, and 30 cm row spacing was followed for cowpea. For nutrient management, nitrogen was applied in two equal splits for both crops: half as a basal dose in furrows at sowing (62.5 kg/ha for toria and 20 kg/ha for cowpea) and the remaining half top-dressed at 30 days after sowing (DAS) in the form of urea. Phosphorus was applied at sowing using single super phosphate (SSP) at a rate of 20 kg/ha for toria and 55 kg/ha for cowpea. Irrigation was scheduled uniformly for both crops: the first irrigation was applied four weeks after sowing, and the second during the second fortnight of November. Manual thinning was done at 25 DAS to maintain optimum plant population (10 cm spacing for toria), and weed control was managed through two hand hoeing at 30 and 60 DAS. Aphid management was conducted using Actara 25 WG (thiamethoxam) at 40 g/acre, applied uniformly to both crops. The cowpea crop was harvested in November for fodder purposes, while toria was harvested in December when the siliquae turned yellow. The toria crop was then stacked for 7days prior to threshing.

Biometric and yield-related observations were recorded at regular intervals to evaluate crop performance. Plant height was measured on five randomly tagged plants per plot at 15-day intervals until harvest, from the base to the tip of the main stem, and the mean height was expressed in centimeters (cm). The number of branches per plant was also recorded at each observation, and the mean was calculated accordingly. The number of leaves per plant was counted at 30, 60 DAS, and at harvest. The Leaf Area Index (LAI) was determined at the same intervals using a leaf area meter, where leaves from five randomly selected plants were scanned, and readings were summed to calculate total leaf area. Dry matter accumulation was measured using a destructive sampling method. Two plants from the border rows of each plot were sampled at 30, 60 DAS, and at harvest, sun-dried initially, then oven-dried at 60 ± 2°C until a constant weight, and weighed to determine dry matter (g/plant). At harvest, siliquae per plant were counted on three tagged plants, and ten siliquae per plot were randomly selected to determine the average number of seeds per siliqua. For yield determination, produce harvested from the net plot area was sun-dried, threshed, and the seed yield was weighed and converted to quintals per hectare (q/ha). Similarly, the stover yield was calculated after threshing. The harvest index was computed as the ratio of grain yield (economic yield) to total biological yield (biomass yield). All observations were averaged and statistically analyzed as per standard procedure. Similarly, growth and yield attributes of cowpea were recorded at defined intervals to assess crop performance.

3. Results and Discussion

Growth parameters of toria

The growth performance of toria (*Brassica campestris L.)* was significantly influenced by intercropping with cowpea under different spacing and row ratio configurations, as reflected in parameters such as plant height, number of branches per plant, leaf area index (LAI), and dry matter accumulation. Among all treatments, T7 [Toria 90 cm + Cowpea fodder (1:3)] consistently demonstrated superior growth, recording the highest plant height (103.2 cm), maximum number of branches (12.83 per plant), peak LAI (4.82 at 60 DAS), and the greatest dry matter accumulation (22.26 g/plant at harvest), closely followed by T6 [Toria 90 cm + Cowpea fodder (1:2)]. These improvements are attributed to better spatial arrangement, enhanced light interception, efficient nutrient utilization, and greater functional leaf area under wider spacing and higher legume proportion, which fostered a more favorable microenvironment for plant development. The increasing trend in dry matter accumulation with crop age further supports the enhanced biomass production in these intercropping systems. These findings are in agreement with earlier reports by Ali and Moinuddin (2016), Khonde et al. (2018), Ray (2023), Maitra et al. (2023), and Layek et al. (2023), who similarly observed improved growth and physiological performance in well-structured cereal-legume intercropping systems.

Growth parameters of cowpea

The growth parameters of cowpea- namely plant height, number of leaves, and number of nodules per plant as shown in table 2, were notably influenced by different intercropping arrangements with toria, particularly under varying spacing and row ratios. Plant height consistently increased with crop age, with the tallest plants recorded in treatment T7 [Toria 90 cm + Cowpea fodder (1:3)] across all stages (23.25 cm at 15 DAS, 54.34 cm at 30 DAS, and 73.14 cm at harvest). This was statistically comparable to T6, yet significantly higher than the remaining treatments. The enhanced plant height under wider spacing may be due to better light penetration and efficient utilization of soil nutrients. A similar pattern was seen in the number of leaves per plant, which also rose with crop maturity. T7 produced the highest leaf count (12.96 at 15 DAS, 23.64 at 30 DAS, and 27.16 at harvest), closely followed by T6 and T5. The greater leaf development in these treatments can be attributed to improved spatial conditions and resource availability. Regarding nodulation, the number of nodules per plant increased up to 30 DAS, then stabilized. At 30 DAS, T7 had the highest nodulation (27.24), while T5 led at harvest (31.45), both statistically at par with T6. The increased nodulation in wider intercropping systems suggests better root development and enhanced biological nitrogen fixation. These results are consistent with previous studies by Ali and Moinuddin (2016), Maitra *et al.* (2023), and Khonde *et al.* (2018), which demonstrated that intercropping with optimized spacing enhances overall crop growth and nodulation.

Yield attribute of toria

The yield-contributing traits of toria, including the number of siliquae per plant, seeds per siliqua, and 1000-seed weight were significantly affected by the intercropping systems with cowpea under varying row spacings and ratios table 3. The maximum number of siliquae per plant was observed in T5 (136.3), closely followed by T6 (135.6) and T7 (133.5), which could be attributed to reduced plant competition and better solar radiation interception due to wider 90 cm spacing. These findings are consistent with those reported by Silva *et al.* (2020), Shaker and Nasrollahzadeh (2014), and Banik and Sharma (2009). Similarly, the highest number of seeds per siliqua (20.40) was recorded in T5 and remained statistically at par with T6 and T7, indicating favorable reproductive development under wider spacing. The 1000-seed weight, a critical indicator of grain plumpness, was also significantly influenced by intercropping geometry. T7 recorded the highest value (5.14 g), which was statistically at par with T6 (5.06 g) and T5 (4.89 g), likely due to improved light availability during the seed-filling phase. These results align with the observations of Thuan and Rana (2010), Ray (2023), and Layek *et al.* (2023), who noted enhanced seed development under wider intercropping arrangements. However, despite superior yield attributes in wider spaced treatments, the highest seed yield (15.75 q/ha), stover yield (36.55 q/ha), and harvest index (29.41%) were observed in T8 (Sole Toria 30 cm), highlighting the influence of higher plant population on overall productivity.

Seed and stover yields

Seed yield is a critical indicator for evaluating the performance of intercropping systems, as it reflects the effective utilization of plant biomass and the efficiency of different treatments. The findings presented in table 3 & 4, revealed that the highest seed yield (15.75 q/ha) was recorded under T8 (Sole Toria 30 cm), which was statistically at par with T1 (Toria 30 cm + Cowpea fodder (1:1)), and significantly superior to the other intercropping treatments. This enhanced yield may be attributed to higher plant population and optimal source-sink relationship, where assimilates generated via photosynthesis are effectively partitioned to reproductive structures. In contrast, treatments with wider row spacings resulted in lower yields, likely due to reduced plant population and suboptimal resource use. These observations align with those of Choudhary *et al.* (2022), Maitra *et al.* (2023), and Silva *et al.* (2020), who all reported yield advantages in toria + cowpea intercropping systems. Regarding stover yield, which also holds economic importance as livestock fodder, the highest values were again noted under T8 (36.55 q/ha) and T1 (35.14 q/ha), both significantly outperforming the other treatments. This can be attributed to denser toria populations in narrower spacing, which enhanced total above-ground biomass. Similar trends were documented by Lal *et al.* (2016), Ray (2023), Dikr and Tadesse (2021), and Banik and Sharma (2009), emphasizing the value of closer row arrangements in intercropping for maximizing both grain and stover yields.

Harvest index

The harvest index serves as an important indicator of how effectively a crop converts the assimilated photosynthates from vegetative parts (source) into economic yield (sink), such as seeds. Data presented in table 3, reveal that the harvest index was significantly influenced by the intercropping system. The maximum harvest index (29.41%) was recorded in T8 (Sole Toria 30 cm), which was statistically comparable to T1 (Toria 30 cm + Cowpea fodder (1:1), 26.10%) and significantly higher than the other treatments. This improvement in harvest index under narrower spacing and sole cropping may be attributed to better partitioning of assimilates towards seed production, influenced by favorable plant population and reduced competition. Treatments with wider spacing exhibited lower harvest index values, possibly due to excessive vegetative growth and less seed yield. Similar trends were also reported by Ray (2023), Layek *et al.* (2023), and Khonde *et al.* (2018), highlighting the role of crop geometry and row ratio in optimizing harvest index in intercropping systems.

Green fodder yield of cowpea

The green fodder yield of cowpea showed significant variation across different intercropping treatments, indicating the varying table 4, efficiency of each system in biomass accumulation during the vegetative phase. The highest yield of 234.98 q/ha was observed in T8 (sole cowpea at 30 cm), which was statistically similar to T7 (Toria at 90 cm + Cowpea fodder in a 1:3 ratio) and T1 (Toria at 30 cm + Cowpea fodder at 1:1), suggesting that both sole cropping and certain intercropping arrangements can enhance fodder production. The integration of cowpea with toria in intercropping system contributed to increased green fodder yield, demonstrating the complementary growth dynamics between the crops. These findings align with the studies of Maitra *et al.* (2023) and Silva *et al.* (2020), who reported that specific intercropping row spacings significantly boost cowpea green fodder yield, offering both economic and fodder advantages in such intercropping systems.

Toria equivalent yield (TEY) and Land equivalent ratio (LER)

The data on toria equivalent yield (TEY) presented in table 4, shows that the maximum TEY (22.28 q ha^{-1}) was observed in T1 (toria 30 cm + Cowpea fodder 1:1), which was significantly higher than all other treatments, followed by T2 (Toria 45 cm + Cowpea fodder 1:1) with a TEY of 18.47 q ha^{-1}. Similarly, the maximum land equivalent ratio (LER) of 1.75 was also recorded under T1, followed by T2 with an LER of 1.60. The higher TEY and LER values in these treatments may be attributed to the complementary interactions between toria and cowpea, wherein cowpea, being a legume, fixes atmospheric nitrogen and improves soil fertility, thereby enhancing the growth and productivity of toria. These findings are in agreement with the earlier reports of Ray (2023), Layek et al. (2023), and Khonde et al. (2018), who also observed similar trends of improved yield and resource-use efficiency under toria–legume intercropping systems.

Quality parameters of toria

The quality parameters of toria grains, including oil content, oil yield, protein content, and protein yield, were significantly influenced by different intercropping systems, as presented in Table 5. Among all treatments, the highest and statistically significant oil content (42.14%) was recorded under T8 (Sole Toria 30 cm), which was at par with T1 (Toria 30cm + Cowpea fodder (1:1)) showing 42.04% oil content. Similarly, oil yield was also highest in T8 (6.63 kg/ha), followed by T1

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(5.20 kg/ha), both of which were statistically comparable. Protein content followed a similar trend, with T8 exhibiting the maximum value (22.28%), significantly higher than all other treatments and statistically at par with T1 (21.34%). Protein yield was also found to be highest in T8 (3.50 kg/ha), closely followed by T1 (2.64 kg/ha). These findings are supported by earlier research by Silva *et al.* (2020), Maitra *et al.* (2023), Khonde *et al.* (2018), Ray *et al.* (2022), and Layek *et al.* (2023), who reported that sole cropping systems often result in higher quality attributes due to reduced competition and improved nutrient uptake, thereby enhancing oil and protein accumulation in grains.

Table 1: Effect of intercropping systems on plant height, number of branches per plants and leaf area index of toria.

Intercropping system	Plant height			Branches per plant			Leaf area index			Dry accumulation		
	30 Days	60 Days	At Harvest	30 Days	60 Days	At Harvest	30 Days	60 Days	At Harvest	30 Days	60 Days	At Harvest
T1 = Toria 30cm + Cowpea fodder (1:1)	34.1	84.1	91.2	3.83	8.70	9.13	1.36	3.82	3.24	3.36	11.31	21.42
T2 = Toria 45cm + Cowpea fodder (1:1)	34.1	88.3	95.1	4.23	9.33	9.63	1.49	4.00	3.33	3.52	11.44	21.58
T3 = Toria 60cm + Cowpea fodder (1:1)	38.2	92.1	100.4	4.73	9.76	10.30	1.59	4.15	3.47	3.64	11.65	21.74
T4 = Toria 60cm + Cowpea fodder (1:2)	42.1	94.1	101.2	5.36	10.60	11.30	1.72	4.37	3.42	3.89	11.89	21.94
T5 = Toria 90cm + Cowpea fodder (1:1)	45.2	96.4	102.1	5.63	11.16	12.11	1.79	4.59	3.55	4.06	12.08	22.02
T6 = Toria 90cm + Cowpea fodder (1:2)	46.1	98.1	103.1	5.96	12.30	12.36	1.94	4.74	3.70	4.35	12.32	22.15
T7 = Toria 90cm + Cowpea fodder (1:3)	46.2	98.2	103.2	6.20	12.70	12.83	2.02	4.82	3.77	4.56	12.45	22.26
T8 = Sole Toria 30 cm	32.3	81.3	89.3	3.36	7.66	9.45	1.24	3.60	3.42	3.15	11.26	21.34
SE m±	0.05	0.27	0.46	0.13	0.17	0.19	0.07	0.16	0.06	0.08	0.32	0.65
CD (p=0.05)	0.14	0.84	0.14	0.39	0.51	0.59	0.23	0.48	0.20	0.24	0.97	1.95

Table 2: Effect of intercropping systems on plant height, number of leaves per plants and number of nodules per plant of cowpea fodder

Intercropping system	Plant height			Number of leaves per plant			Number of nodules per plant	
	15 Days	30 Days	At Harvest	15 Days	30 Days	At Harvest	30 Days	At Harvest
T1 = Toria 30cm + Cowpea fodder (1:1)	19.56	47.14	64.36	8.15	16.86	19.45	21.36	23.43
T2 = Toria 45cm + Cowpea fodder (1:1)	21.23	49.65	66.14	10.18	18.33	21.56	23.47	25.66
T3 = Toria 60cm + Cowpea fodder (1:1)	21.47	51.14	68.36	11.26	19.16	22.37	24.16	27.14
T4 = Toria 60cm + Cowpea fodder (1:2)	22.14	52.36	69.16	11.48	20.14	23.14	24.95	24.35
T5 = Toria 90cm + Cowpea fodder (1:1)	22.34	53.45	71.26	12.32	23.06	25.47	25.15	31.45
T6 = Toria 90cm + Cowpea fodder (1:2)	23.16	54.26	72.54	12.79	23.17	26.24	26.55	31.15
T7 = Toria 90cm + Cowpea fodder (1:3)	23.25	54.34	73.14	12.96	23.64	27.16	27.24	30.67
T8 = Sole Toria 30 cm	19.25	45.64	62.16	8.44	18.16	19.94	22.14	24.24
SE m±	0.10	0.14	0.23	0.12	0.21	0.57	0.71	0.67
CD (p=0.05)	0.31	0.43	0.71	0.36	0.60	1.70	2.10	1.79

Table 3: Effect of intercropping systems on yield parameter of toria

Intercropping system	Number of siliquae per plant	Number of seeds per siliqua	1000- seed weight (g)	Seed yield (q/ha)	Stover yield (q/ha)	Harvest index (%)
T1 = Toria 30cm + Cowpea fodder (1:1)	120.0	18.63	4.14	12.38	35.14	26.10
T2 = Toria 45cm + Cowpea fodder (1:1	122.6	19.23	4.29	10.67	31.25	25.53
T3 = Toria 60cm + Cowpea fodder (1:1)	130.3	19.46	4.48	9.54	29.15	24.73
T4 = Toria 60cm + Cowpea fodder (1:2)	128.6	18.76	4.71	8.77	28.58	23.53
T5 = Toria 90cm + Cowpea fodder (1:1)	136.3	20.40	4.89	7.44	27.25	21.43
T6 = Toria 90cm + Cowpea fodder (1:2)	135.6	20.33	5.06	7.25	26.46	21.52
T7 = Toria 90cm + Cowpea fodder (1:3)	133.5	20.15	5.14	7.15	25.15	22.17
T8 = Sole Toria 30 cm	123.6	19.46	4.64	15.75	36.55	29.41
SE m±	0.92	0.97	0.13	1.25	0.68	1.12
CD (p=0.05)	2.89	0.29	0.39	3.40	2.01	3.35

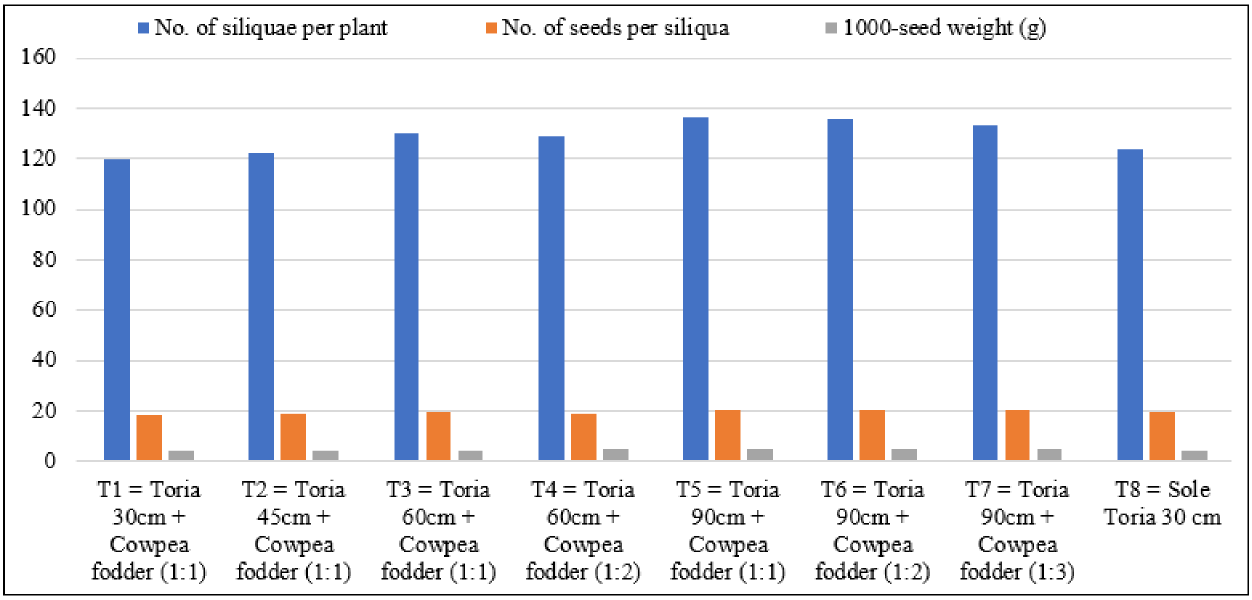

Figure 3.1: Effect of intercropping system on number of siliquae per plant, number of seeds per silique, 1000 seed weight of toria

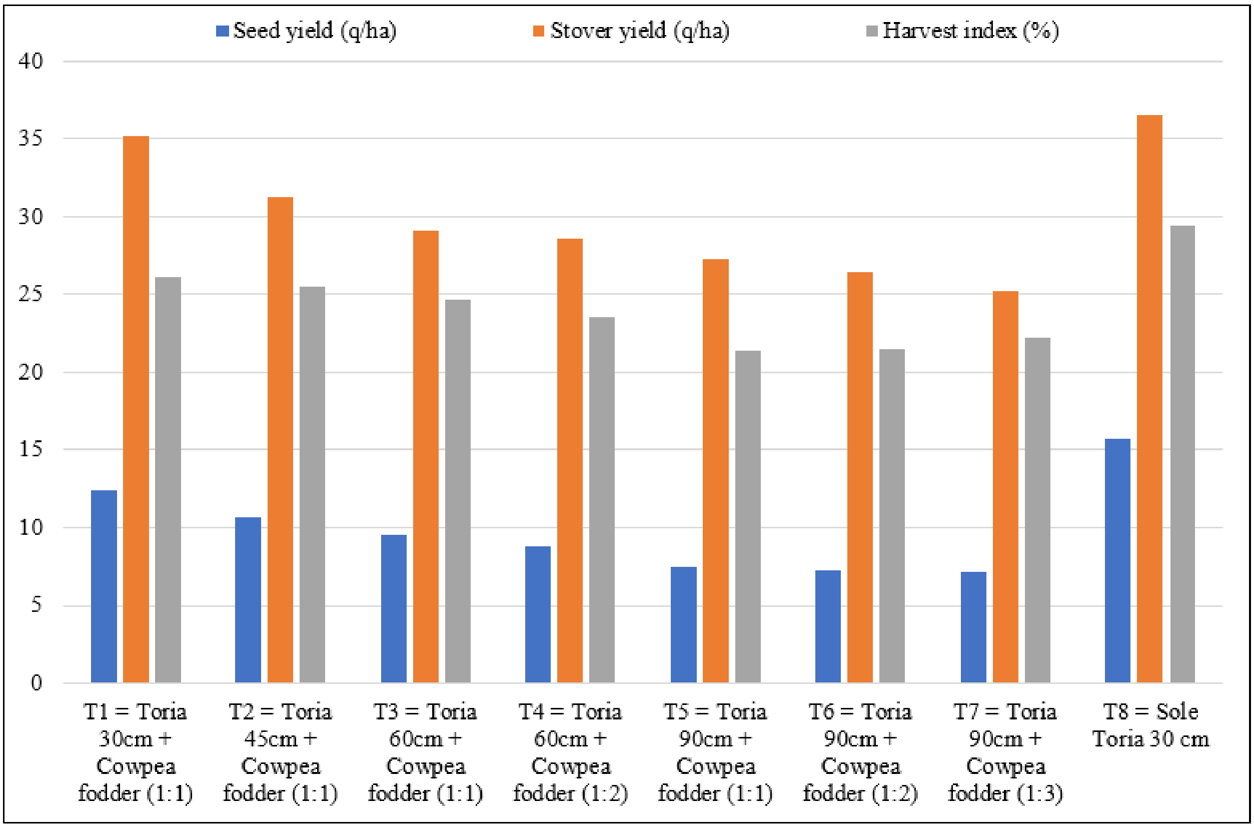

Figure 3.2: Effect of intercropping systems on seed yield, stover yield and harvest index of toria

Table 4: Effect of intercropping systems on green fodder yield of cowpea

Intercropping system	Seed yield of toria (q/ha)	Green fodder yield of cowpea (q/ha)	Toria equivalent yield (TEY) (q/ha)	Land equivalent ratio (LER)
T1 = Toria 30cm + Cowpea fodder (1:1)	12.38	229.35	20.49	1.75
T2 = Toria 45cm + Cowpea fodder (1:1	10.67	220.47	18.47	1.60
T3 = Toria 60cm + Cowpea fodder (1:1)	9.54	212.55	17.06	1.50
T4 = Toria 60cm + Cowpea fodder (1:2)	8.77	226.74	16.79	1.51
T5 = Toria 90cm + Cowpea fodder (1:1)	7.44	120.55	11.70	0.98
T6 = Toria 90cm + Cowpea fodder (1:2)	7.25	218.35	14.97	1.38
T7 = Toria 90cm + Cowpea fodder (1:3)	7.15	232.46	15.37	1.43
T8 = Sole Toria 30 cm	15.75	-	15.75	-
T9= Sole Cowpea fodder 30cm	-	234.98	8.31	-
SE m±	1.25	2.17	0.46	-
CD (p=0.05)	3.40	7.66	1.62	-

Table 5: Effect of intercropping systems on quality parameters of toria

Intercropping system	Oil content (%)	Oil yield (kg/ha)	Protein content (%)	Protein yield (kg/ha)
T1 = Toria 30cm + Cowpea fodder (1:1)	42.04	5.20	21.34	2.64
T2 = Toria 45cm + Cowpea fodder (1:1)	41.60	4.43	21.26	2.26
T3 = Toria 60cm + Cowpea fodder (1:1)	41.55	3.96	20.80	1.98
T4 = Toria 60cm + Cowpea fodder (1:2)	41.17	3.61	20.15	1.76
T5 = Toria 90cm + Cowpea fodder (1:1)	40.18	2.98	20.00	1.48
T6 = Toria 90cm + Cowpea fodder (1:2)	41.16	2.98	20.05	1.45
T7 = Toria 90cm + Cowpea fodder (1:3)	41.06	2.93	20.66	1.47
T8 = Sole Toria 30 cm	42.14	6.63	22.28	3.50
SE m±	0.10	0.51	0.32	0.29
CD (p=0.05)	0.30	1.54	0.95	0.87

4. Conclusion

The study demonstrated that intercropping Toria (Brassica campestris L.) with Cowpea fodder under varied spacing and row ratio configurations significantly impacts crop growth, yield attributes, biomass accumulation, and quality parameters. While sole cropping of Toria at 30 cm spacing (T8) consistently produced the highest seed and stover yields, oil and protein content, intercropping systems such as T1 (Toria 30 cm + Cowpea 1:1) and T7 (Toria 90 cm + Cowpea 1:3) demonstrated substantial benefits by combining competitive seed and fodder yields with enhanced resource use efficiency and soil health benefits from legume inclusion. Notably, T7 exhibited superior growth parameters and dry matter accumulation due to improved microclimatic conditions and spatial arrangement, whereas T1 emerged as the most balanced treatment, delivering high yields and superior quality while supporting sustainable production. These results highlight the potential of optimized intercropping systems to maximize land use, maintain soil fertility, and improve farm returns, making them a viable strategy for sustainable agriculture in the agro-climatic conditions of Punjab.

References

[1] Ali, F., & Moinuddin, F. A. (2016). Effects of intercropping on plant growth and yield performance of toria (*Brassica campestris* L.) and field pea (*Pisum sativum* L.) under irrigated conditions. *Agricultural Science Digest*. 30(24), 234-256.

[2] Alla, W. H., Shalaby, E. M., Dawood, R. A., & Zohry, A. A. (2014). Effect of cowpea (Vigna sinensis L.) with maize (Zea mays L.) intercropping on yield and its components. *International Scholarly and Scientific Research & Innovation*, *8*(11), 1258-1264.

[3] Altieri, M. A., Nicholls, C. I., & Montalba, R. (2017). Technological approaches to sustainable agriculture at a crossroads: An agroecological perspective. *Sustainability*, *9*(3), 349.

[4] Banik, P., & Sharma, R. C. (2009). Yield and resource utilization efficiency in baby corn legume-intercropping system in the Eastern Plateau of India. *Journal of sustainable agriculture*, *33*(4), 379-395.

[5] Belel, M. D., Halim, R. A., Rafii, M. Y., & Saud, H. M. (2014). Intercropping of corn with some selected legumes for improved forage production: A review. *Journal of Agricultural Science*, *6*(3), 48.

[6] Bora, P., Ojha, N. J., & Kurmi, K. (2022). Growth and yield performance of late sown Toria (Brassica rapa subsp. Toria) under integrated nutrient management practices in Assam.

[7] Brooker, R. W., Bennett, A. E., Cong, W. F., Daniell, T. J., George, T. S., Hallett, P. D., & White, P. J. (2015). Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology. *New Phytologist*, *206*(1), 107-117.

[8] Choudhary, S., Barkha, S. S., & Bokado, K. (2022). Productivity and profitability of toria (*Brassica campestris* L. var. toria) as influenced by integrated nutrient management in trans-gangetic plains of Punjab. In *Biological Forum–An International Journal* (Vol. 14, No. 2, pp. 1446-1450).

[9] Dikr, W., & Tadesse, N. (2021). Intercropping of newly released common bean varieties with maize at Jejebicho research station in Sankura wereda silte zone of southern Ethiopia.

[10] Khonde, P., Congo, R. D., Tshiabukole, K., Congo, R. D., Kankolongo, M., Congo, R. D., & Nkongolo, K. (2018). Evaluation of yield and competition indices for intercropped eight maize varieties, soybean and cowpea in the zone of savanna of South-West RD Congo. *Open Access Library Journal*, *5*(01), 1.

[11] Lal, B., Rana, K. S., Gautam, P., Rana, D. S., Shivay, Y. S., Meena, B. P., & Singh, P. (2016). Ethiopian mustard–chickpea intercropping system is a viable option for yield advantage in dryland condition of north India-Part II. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*, *86*, 757-766.

[12] Layek, J., Das, A., Mitran, T., Nath, C., Meena, R. S., Yadav, G. S., & Lal, R. (2023). Cereal+ legume intercropping: An option for improving productivity and sustaining soil health. *Legumes for soil health and sustainable management*, 347-386.

[13] Maitra, S., Shankar, T., Gaikwad, D. J., & Sairam, M. (2023). Influence of maize-cowpea intercropping system on growth, productivity and competitive ability of crops cultivated under south Odisha conditions.

[14] Ray, M. (2023). *Planting pattern and nutrient management in rainfed sweet corn+ cowpea system and its residual effect on succeeding toria* (Doctoral dissertation, Department of Agronomy, OUAT, Bhubaneswar).

[15] Ray, M., Roul, P., Behera, B., Sahoo, K., Mishra, N., & Das, S. (2022). Analysis of productivity and profitability of sweet corn+ cowpea intercropping under rainfed condition in NCPZ of Odisha. *International Journal of Environment and Climate Change*, *12*(11), 1335-1347.

[16] Shaker, K. S., & Nasrollahzadeh, S. (2014). Evaluation of yield and advantage indices of sorghum (*Sorghum*

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bicolor L.) and mungbean (*Vigna radiate* L.) intercropping systems.

[17] Silva, J. N. D., Bezerra, F., Lima, J. S. S. D., Chaves, A. P., Nunes, R. L. C., Rodrigues, G. S. D. O., & Santos, E. C. D. (2020). Sustainability of carrot-cowpea intercropping systems through optimization of green manuring and spatial arrangements. *Ciência Rural*, *51*(1), e20190838.

[18] Thuan, N. T. Q., & Rana, D. S. (2010). Productivity and response of quality brassicas (*Brassica sp.*)–cowpea (*Vigna unguiculata*) sequence under different sources of nutrients and sulphur levels. *Indian Journal of Agronomy*, *55*(4), 264-269