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COMPETITIVE ABILITY OF *PARTHENIUM HYSTEROPHORUS* WITH DIRECT SEEDED RICE AND INFLUENCE OF PARTHENIUM FLOWERING DYNAMICS WITH METEOROLOGICAL FACTORS

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ABSTRACT

Parthenium hysterophorus, an invasive weed, significantly threatens agricultural productivity, particularly in direct-seeded rice (DSR) systems. This study investigates the competitive interactions between parthenium and dry direct-seeded rice, emphasizing the impact on growth, yield and flowering dynamics of parthenium in relation to meteorological factors. A pot experiment was conducted using different rice-to-parthenium ratios (4:0, 3:1, 2:2, 1:3, 0:4) in a completely randomized design with six replications per treatment. Key competitive indices such as Relative Yield (RY), Relative Yield Total (RYT), Competitive Ratio (CR), Aggressivity (A), Relative Crowding Coefficient (RCC), Competitive Balance Index (CBI), Neighbourhood Competitive Index (NCI), and Land Equivalent Ratio (LER) were calculated. The results indicated that as the density of parthenium increased, rice growth and yield significantly declined by 37.5 to 72.5%. The flowering dynamics of parthenium were closely linked to temperature and humidity, with moderate to low temperatures and high humidity favouring prolific flowering. So, controlling this weed during this period or within two months of sowing rice can help minimize its harmful impact on rice cultivation in affected regions of Karaikal.

Keywords **:** Competitive indices, Flowering dynamics, Growth and Yield.

Introduction

Parthenium hysterophorus, commonly known as parthenium weed, is an aggressive invasive species that has become a significant concern in agricultural systems worldwide (Bajwa *et al*., 2019). Originating from America, this weed has rapidly spread across continents, infesting croplands, pastures and non-crop areas. Its competitive ability, allelopathic effects and adaptability to various climatic conditions have made it a challenging weed (Safdar *et al*., 2016). One of the critical areas of concern is its impact on direct-seeded rice, a widely adopted cultivation practice due to its labour and water-saving benefits.

Direct-seeded rice (DSR) has gained popularity as an alternative to traditional transplanting methods, offering advantages such as reduced water usage, lower labour costs and shorter crop duration (Saravanane and Karthickraja, 2024). However, the open-field environment and the absence of water-logged conditions in DSR systems create a favourable habitat for weeds especially parthenium. The presence of this weed can significantly affect crop growth, yield and overall agricultural productivity. Understanding the competitive interactions between direct-seeded rice and parthenium is crucial for developing effective weed management strategies.

The flowering ability of parthenium is another vital aspect that influences its spread and persistence. Flowering phenology is closely linked to meteorological factors such as temperature, rainfall, humidity and photoperiod (Saravanane *et al*., 2023). These environmental conditions can affect the timing and duration of flowering, seed production and subsequent weed proliferation. Investigating the relationship between meteorological variables and the flowering dynamics of parthenium can provide insights into its reproductive behaviour and identify optimal time for implementing targeted control measures.

Hence a pot experiment was conducted to explore the competitive ability of parthenium with direct-seeded rice, to work out the competitive indices of parthenium with direct-seeded rice and examine how meteorological factors influence its flowering ability. By understanding these interactions, adaptations can be developed that minimize the adverse effects of parthenium on rice production. This study will contribute to sustainable agricultural practices and help mitigate the challenges this invasive weed poses in rice-growing regions.

Material and Methods

A pot experiment was conducted at the AICRP-WM sponsored lab at Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Puducherry UT (10° 55′ N latitude and 79° 49′ E longitude, 4 m above mean sea level), India during August-September 2022. The meteorological parameters are presented in Fig. 1. The soil was neutral in pH (6.61) with the texture of sandy clay loam, low in available N (141.1 kg/ha), high in available P (31.8 kg/ha) and medium in available K (188.8 kg/ha).

Experimental setup

The experiment was arranged in completely randomized design with six replications per treatment in pots. The five treatments consisted of different rice to parthenium ratios: 4:0, 3:1, 2:2, 1:3 and 0:4 (Fig. 2). All the weed species in the pots were removed to focus on the competitive ability of parthenium with rice.

Plant material preparation

Parthenium was collected around college, sun-dried and the flowers were crushed by hands to collect the seeds. The healthy seeds were soaked in water overnight and tied with cotton cloth to induce early germination. Rice seeds (cultivar 'ASD 16' with duration of 110 days) were sown on the fourth week of August and harvested during the second week of December. Parthenium seeds were sown twenty days before rice to synchronize their germination with the emergence of rice seedlings. This method ensured that both crop and weed competed with each other throughout their growth cycles, allowing for a comprehensive study of their mutual interactions.

Experimental procedure

Each experimental pot was filled with soil and levelled by hands for even water distribution. A germination test was conducted on the certified ASD 16 seeds by sowing them on a petri dish and evaluating them after three days. The results indicated an average germination rate of 98.0%, confirming the seed viability. Manual seeding was done in each pot with appropriate ratios according to treatments, adopting a spacing of 10 cm × 10 cm, and the seeds were covered with soil. The pots were surface watered immediately after sowing.

Competitive indices calculations

From this, the following competitive indices of parthenium with direct-seeded rice were calculated.

1. Relative Yield (RY):

Relative Yield (RY) is the yield of a species grown in mixture relative to its yield when grown in monoculture. It helps in understanding the performance of a species in the presence of competitors (De Wit, 1960).

$$RY = \frac{\text{Yield in mixture}}{\text{Yield in monoculture}}$$

2. Relative Yield Total (RYT):

Relative Yield Total (RYT) is the sum of the relative yields of all species in the mixture. It indicates the overall productivity of the mixed cropping system (Willey and Rao, 1980).

$$RYT = RY_{\text{rice}} + RY_{\text{parthenium}}$$

3. Competitive Ratio (CR):

Competitive Ratio (CR) quantifies the competitive ability of one species relative to another (Willey and Rao, 1980).

$$CR_{\text{species A}} = \frac{RY_{\text{species A}}}{RY_{\text{species B}}}$$

4. Aggressivity (A):

Aggressivity (A) measures the competitive dominance of one species over another (McGilchrist and Trenbath, 1971).

$$A_{\text{rice}} = \frac{\text{Yield of rice in mixture}}{\text{Yield of rice in monoculture}} - \frac{\text{Yield of parthenium in mixture}}{\text{Yield of parthenium in monoculture}}$$

$$A_{\text{parthenium}} = (-A_{\text{rice}})$$

5. Relative Crowding Coefficient (RCC):

Relative Crowding Coefficient (RCC) evaluates the relative competitiveness and efficiency of resource use (De Wit, 1960).

$$\mathrm{RCC} = \frac{\text{Yield of species A in mixture}}{\text{Yield of species A in monoculture}} \times \frac{\text{Yield of species B in monoculture}}{\text{Yield of species B in mixture}}$$

6. Competitive Balance Index (CBI):

Competitive Balance Index (CBI) measures the balance between the competitive abilities of two species (Wilson, 1988).

$$\mathrm{CBI} = \frac{\mathrm{CR}_{\text{species A}} - \mathrm{CR}_{\text{species B}}}{\mathrm{CR}_{\text{species A}} + \mathrm{CR}_{\text{species B}}}$$

7. Neighbourhood Competitive Index (NCI):

NCI evaluates the impact of neighbouring plants on the growth of a target plant (Willey, 1979).

$$\mathrm{NCI} = \frac{\text{Yield of rice }_{\text{(in mixture)}}}{\text{Distance between crops}}$$

8. Land Equivalent Ratio (LER):

LER assesses the efficiency of land use in mixed cropping compared to monoculture (Willey, 1979).

$$\mathrm{LER} = \frac{\text{Yield of species in mixture}}{\text{Yield of species in monoculture}}$$

Statistical analysis

The response of parthenium flowering concerning meteorological parameters was done using R-software (R core team, 2018). An analysis of variance (ANOVA) was executed among treatments. Wherever the treatments were significant, CD was calculated and inferences were drawn at a 5 percent level of significance.

Results and Discussions

Growth and yield attributes of rice in competition with parthenium

The growth and yield attributes of rice in competition with parthenium are given in Table 1. In T_1 (4 rice: 0 parthenium), rice exhibited optimal growth with a plant height of 77.4 cm, root length of 31.5 cm, 50% flowering at 76.8 DAS, a root-to-shoot ratio of 0.8, yield of 4.0 t/ha, and dry matter production (DMP) of 2.6 t/ha. In mixed treatments, rice growth was generally suppressed by the presence of parthenium. As the density of parthenium increases, growth and yield attributes decline accordingly. In T_2 (3 rice: 1 parthenium), rice height decreased by 9.4% and yield dropped by 37.5%, while parthenium showed considerable growth with a height of 71.3 cm and yield of 2.0 t/ha. This trend continued in other mixed treatments, with T_3 (2 rice: 2 parthenium) showing a 5.3% reduction in plant height and a 50.0% reduction in yield, and T_4 (1 rice: 3 parthenium) showing a 16.4% reduction in plant height and a 72.5% reduction in yield, while parthenium growth remained robust. In T_5 (0 rice: 4 parthenium), rice was absent and parthenium achieved a height of 68.5 cm and yield of 3.8 t/ha. Among parthenium, T_2 exhibited higher plant height, indicating that parthenium tends to dominate when solo. However, when in mixed stands, the plant height of parthenium decreased by 3.9% to 10.4%.

Parthenium hysterophorus is known for its strong allelopathic effects, which interfere with rice physiological processes, reducing plant height, root development and overall biomass accumulation (Saravanane *et al.*, 2023). Additionally, vigorous growth and high reproductive capacity allow it to outcompete rice for essential resources such as light, water and nutrients. The dense canopy and extensive root system of parthenium can overshadow rice plants, reducing their photosynthetic efficiency and limiting their access to soil moisture and nutrients.

The observed trends highlight the competitive superiority of parthenium over rice, significantly affecting the growth and yield of rice. These findings are consistent with previous studies indicating that the allelopathic properties and rapid development of parthenium confer a competitive advantage in mixed cropping systems (Bajwa *et al.*, 2016; Bajwa *et al.*, 2019). Parthenium weed competition for longer durations severely affects crop growth, as it attains more height and dry biomass over time. If parthenium is not controlled, it can lead to a 37.5% to 72.5% yield loss in direct-seeded rice. Therefore, effective control measures should be implemented within two months to prevent significant yield losses

Competitive indices of direct seeded rice with *parthenium hysterophorus*

The experiment evaluated the competitive interactions between direct-seeded rice and *Parthenium hysterophorus* across various treatments with differing rice ratios to parthenium ratios (Table 2).

In treatments, where rice was grown alone (T_1: 4 rice: 0 parthenium), the absence of parthenium allowed rice to thrive without competition, resulting in maximum yield (4.0 t/ha). This is reflected in the RY and RYT values of 0.00, indicating no yield reduction in monoculture conditions. Similarly, all competitive indices (CR, A, RCC, CBI, NCI and LER) were negligible, confirming no competitive interactions. This finding is consistent with studies emphasizing the detrimental effects of weed competition on crop yields when grown alone (Willey and Rao, 1980). As the proportion of parthenium increased relative to rice (T_2 to T_5), the competitive dynamics shifted significantly. In T_2 (3 rice: 1 parthenium), although rice yield decreased moderately (2.5 t/ha), parthenium also showed considerable growth (2.0 t/ha), suggesting a competitive advantage for parthenium in mixed stands. The RY for rice (0.63) and RYT (1.15) indicate reduced productivity compared to monoculture, influenced by competitive ability of parthenium. The positive CR (1.19) and moderate A (0.10) indicated that parthenium competes slightly more effectively than rice in this ratio, influencing rice yield negatively. The RCC (0.84) shows a competitive advantage for parthenium, impacting rice yield efficiency (LER = 0.63). In T_3 (2 rice: 2 parthenium), the balance between rice and parthenium yields was closer (rice: 2.0 t/ha; parthenium: 2.5 t/ha), but rice still exhibited reduced RY (0.50) and RYT (1.16), indicating a substantial decrease in productivity due to competitive pressure from parthenium. The CR (0.76) and positive A (0.16) suggest that parthenium competitive advantage over rice intensifies in equal proportions, leading to a higher RCC (1.32) and inefficient in mixed cropping (LER = 0.50). As parthenium dominance increased in T_4 (1 rice: 3 parthenium), rice yield fell (1.1 t/ha), while parthenium yield ascended (3.4 t/ha). The RY for rice drastically decreased (0.28), indicating severe competition-induced yield losses. The negative A (-0.62) underscores increasing dominance of parthenium, reflected in the high RCC (3.25) and adverse CBI (-0.83), highlighting strong competitive balance advantage and inefficient mixed cropping (LER = 0.28). In T_5 (0 rice: 4 parthenium), where only parthenium was present, rice failed to yield (0.0 t/ha), stating parthenium capability to suppress rice growth entirely in the absence of competition. All competitive indices (CR, A, RCC, CBI, NCI, LER) were 0.00, underscoring no competitive interactions due to the absence of rice. Similar findings have been reported in studies highlighting parthenium competitive edge over crops due to its aggressive growth and allelopathic effects (Bajwa *et al*., 2019). Asif *et al.* (2017) reported that higher parthenium result in significant declines in yield and yield components.

Flowering dynamics in relation to meteorological factors

The flowering patterns of *Parthenium hysterophorus* can be related to the temperature and humidity conditions observed during the study period (Fig. 3). This study revealed a clear pattern where flowering intensity increased with slight decreases in temperature and increases in humidity, highlighting the sensitivity of parthenium flowering to these meteorological factors. In October, when maximum temperatures were higher (32.9°C) and relative humidity was moderately high (89.0% at 07:12 h and 66.0% at 14:12 h), treatments showed lower flowering, compared to subsequent months. This suggests that while parthenium can initiate flowering under warm conditions, excessively high temperatures may limit the extent of flowering. This observation is consistent with findings by Baskin and Baskin (1998), who noted that extreme temperatures can adversely affect the growth and reproductive capacity of seeds. As November progressed, temperatures slightly decreased to 30.8°C (max) and 23.2°C (min), with humidity levels increasing (92.0% at 07:12 h and 72.0% at 14:12 h). This period saw a substantial increase in the number of flowers across all treatments, indicating that moderate temperatures coupled with higher humidity favoured robust flowering in parthenium. This trend aligns with research by Kaur *et al.* (2017), who reported that parthenium exhibits vigorous flowering under moderate temperature and high humidity conditions. In December, temperatures further decreased to 29.8°C (max) and 23.0°C (min), while humidity remained high (92.0% at 07:12 h and 75.0% at 14:12 h). Despite slightly cooler temperatures, parthenium continued to flower prolifically, with some treatments showing higher flower counts during the season. Overall, the flowering pattern of parthenium appears to be closely tied to environmental factors, particularly temperature and humidity. These findings underscore the importance of targeted control measures at low temperature and high humidity to suppress flowering and limit the spread (Karthickraja *et al*., 2024).

Conclusion

The study underscores the substantial competitive advantage of *Parthenium hysterophorus* over direct-seeded rice, with significant reductions in rice growth and yield as parthenium density increased. The competitive indices revealed that parthenium consistently outcompeted rice, highlighting the need for timely and effective weed management strategies. Additionally, flowering patterns of parthenium were found to be influenced by weather conditions, with moderate to low temperatures and high humidity fostering vigorous flowering. Controlling this weed during this period or within two months of sowing rice can help minimize its harmful impact on rice cultivation in affected regions of Karaikal.

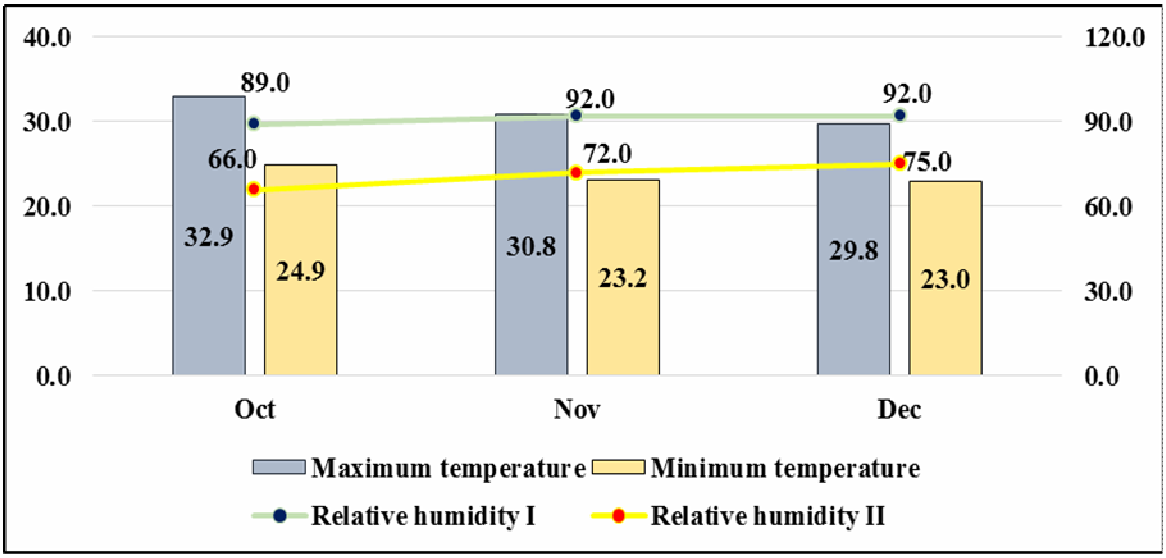

Fig. 1: Meteorological parameters from October to December 2022.

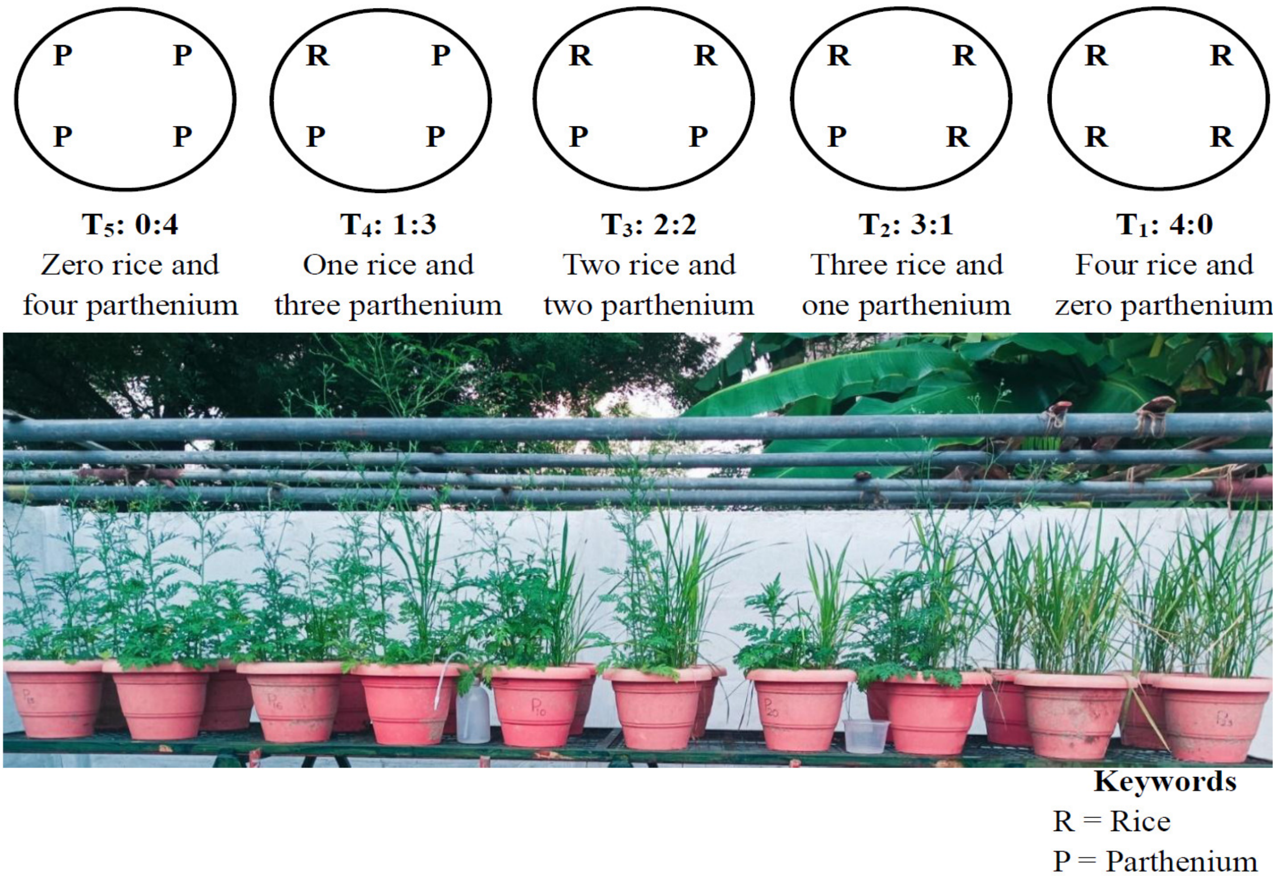

Fig. 2: Schematic layout of rice stands with parthenium.

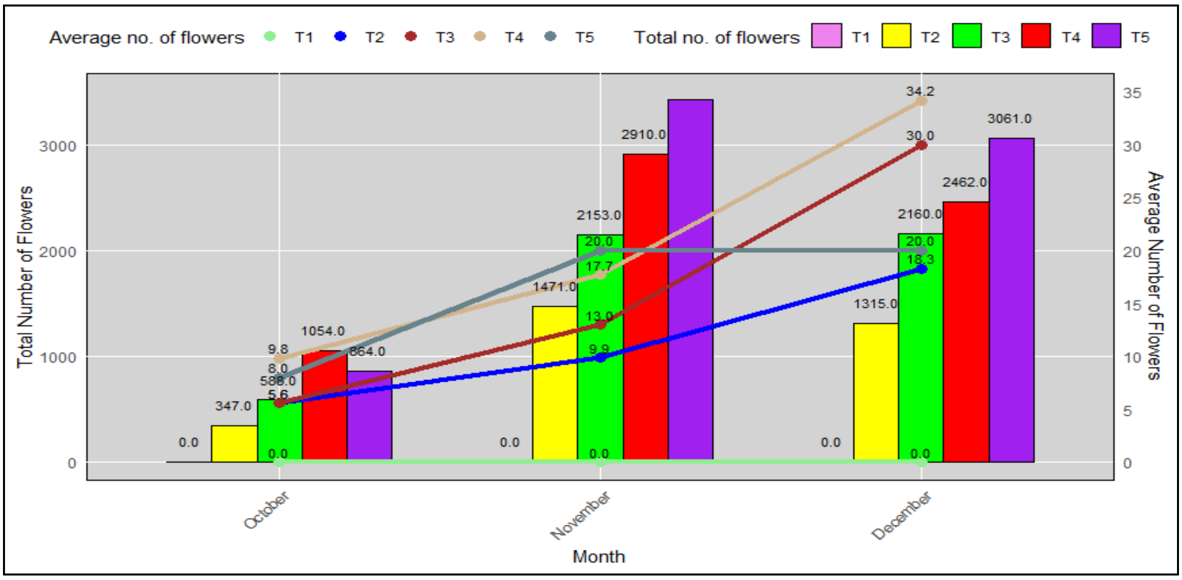

Fig. 3: Response of parthenium flowering concerning meteorological parameters

Table 1: Growth and yield attributes of direct seeded rice in competition with *parthenium hysterophorus*

Treatments	Plant height (cm)		Root length (cm)		50% flowering (DAS)		Root: Shoot		Yield (t/ha)		DMP (t/ha)	
	Rice	Parthe-nium	Rice	Parthe-nium	Rice	Parthe-nium	Rice	Parthe-nium	Rice	Parthe-nium	Rice	Parthe-nium
T_1: (4 rice: 0 parthenium)	77.4	0.0	31.5	0.0	76.8	0.0	0.8	0.0	4.0	0.0	2.6	0.0
T_2: (3 rice: 1 parthenium)	70.1	71.3	27.1	26.7	77.9	76.0	1.4	0.4	2.5	2.0	2.0	3.5
T_3: (2 rice: 2 parthenium)	73.3	64.1	24.3	18.2	80.3	75.3	0.8	0.3	2.0	2.5	2.2	2.7
T_4: (1 rice: 3 parthenium)	64.7	68.2	17.1	26.9	78.2	75.3	0.4	0.3	1.1	3.4	2.9	2.2
T_5: (0 rice: 4 parthenium)	0.0	68.5	0.0	19.7	0.0	75.0	0.0	0.2	0.0	3.8	0.0	2.5
S. Ed	**2.60**	**5.69**	**0.58**	**0.87**	**1.71**	**4.32**	**0.20**	**0.08**	**0.21**	**1.05**	**0.45**	**0.49**
CD (p=0.05)	**5.4**	**11.7**	**1.2**	**1.8**	**3.5**	**8.9**	**0.4**	**0.2**	**0.4**	**2.2**	**0.9**	**1.0**

Table 2: Competitive indices of direct seeded rice with *parthenium hysterophorus*

Treatments	Rice Yield (t/ha)	PY (t/ha)	RY		RYT	CR		A		RCC		CBI	NCI		LER	
			R	P		R	P	R	P	R	P		R	P	R	P
T_1: (4 rice: 0 parthenium)	4.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_2: (3 rice: 1 parthenium)	2.5	2.0	0.63	0.53	1.15	1.19	0.84	0.10	-0.10	1.19	0.84	0.17	0.25	0.20	0.63	0.53
T_3: (2 rice: 2 parthenium)	2.0	2.5	0.50	0.66	1.16	0.76	1.32	-0.16	0.16	0.76	1.32	-0.27	0.20	0.25	0.50	0.66
T_4: (1 rice: 3 parthenium)	1.1	3.4	0.28	0.89	1.17	0.31	3.25	-0.62	0.62	0.31	3.25	-0.83	0.11	0.34	0.28	0.89
T_5: (0 rice: 4 parthenium)	0.0	3.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

PY – Parthenium yield (t/ha); R – Rice; P – Parthenium; RY - Relative Yield; RYT - Relative Yield Total; CR - Competitive Ratio; A – Aggressivity; RCC - Relative Crowding Coefficient; CBI - Competitive Balance Index; NCI - Neighbourhood Competitive Index and LER - Land Equivalent Ratio

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Conflicts of Interest

The authors declare no conflict of interest.

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