Research Article

Unraveling the Competitive Dynamics: Effects of Jungle Rice (*Echinochloa colona* L.) Density on Maize (*Zea mays* L.) Productivity and Quality

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Abstract | Maize (*Zea mays* L.) is a globally significant cereal crop, but its productivity is often constrained by weed competition, particularly from jungle rice (*Echinochloa colona* L.). This study examines the impact of varying densities of jungle rice on maize growth, yield, and quality to identify sustainable weed management strategies. The experiment was conducted at Gomal University, Pakistan, and employed a randomized complete block design with six jungle rice density treatments (0, 5, 10, 15, 20, and 25 plants/m^2). The results revealed that increasing the jungle rice density significantly reduced the maize plant height, grain yield, 1000-grain weight, and leaf area index, whereas lower densities (≤10 plants m^{-2}) had minimal effects. At the highest density (25 plants/m^2), the maize yield and grain protein content were reduced by 59.68% and 13.05%, respectively, compared with those of the control. These findings underscore the competitive threat posed by jungle rice and highlight the necessity of maintaining weed densities below 10 plants m^{-2} to optimize maize productivity and resource use efficiency. This study provides actionable insights for integrated weed management, contributing to sustainable agricultural practices and enhanced profitability in maize-based systems.

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Introduction

Maize (*Zea mays* L.) is one of the most widely cultivated cereal crops in the world and serves as a cornerstone of food security, livestock feed, and industrial applications (Safdar *et al*., 2016). Its global importance stems from its adaptability to diverse agroclimatic conditions, high productivity, and nutritional value. In developing countries, maize plays a vital role in sustaining livelihoods, contributing significantly to rural economies (Sarabi *et al*., 2013). However, the potential of maize to achieve optimal yields is often hampered by numerous biotic and abiotic stresses. Among these factors, weed competition is a major challenge, as it directly impacts crop growth, resource allocation, and final yield (Imoloame and Omalaiye, 2017).

One of the most aggressive weed species that threatens maize production is jungle rice (*Echinochloa colona* L.), a C4 annual grass known for its fast growth, prolific seed production, and high competitive ability (El-Naim *et al*., 2010). Jungle rice thrives in warm and moist environments, conditions often found in maize-growing regions, where it competes fiercely with crops for vital resources such as sunlight, water, nutrients, and space (Elahi *et al*., 2015). Its adaptability to various soil types and ability to complete its life cycle rapidly make it a persistent and formidable competitor (Fahad *et al*., 2014). In many cases, unchecked infestations of jungle rice can cause substantial yield losses in maize, depending on the population density of the weed and the timing of its emergence relative to the crop.

The impact of weed competition, particularly from species such as jungle rice, is not uniform and varies with weed density, crop growth stage, and environmental factors (Iqbal and Cheema, 2008). High densities of jungle rice can exacerbate competition, reducing the ability of maize to utilize resources efficiently (Jabran *et al*., 2010). Conversely, lower densities may have a less pronounced effect (Fahad *et al*., 2014). Understanding these density-dependent interactions is critical for devising targeted weed management strategies that minimize yield losses while maintaining ecological and economic sustainability.

Despite the widespread occurrence of jungle rice in maize fields, few studies have quantified its effects on maize growth and yield across varying population densities. Such knowledge is essential for developing integrated weed management (IWM) practices that balance the use of herbicides with cultural and mechanical control methods. Furthermore, the insights gained can inform predictive models of yield loss and help farmers optimize their input costs while protecting environmental health.

In this context, the present study aims to evaluate the effects of varying population densities of jungle rice (*Echinochloa colona* L.) on maize (*Zea mays* L.) growth, yield, and resource use efficiency. By examining the competitive dynamics between maize and jungle rice, this research seeks to provide actionable recommendations for effective weed management in maize cropping systems, ultimately contributing to sustainable agricultural practices and enhanced productivity.

Materials and Methods

This study was designed to evaluate the effects of varying population densities of jungle rice (*Echinochloa colona* L.) on maize (*Zea mays* L.) growth and yield at Gomal University, Dera Ismail Khan, KPK, Pakistan. The experiment was conducted following a randomized complete block design (RCBD) with four replications. The details of the methodology are as follows:

Experimental site preparation

The experimental field was prepared to achieve a fine tilth by plowing with two passes each of a tiller, disc harrow, and rotavator. The prepared soil provided an optimal environment for seed germination and plant establishment.

Plot layout and treatments

The experiment included plots measuring 3 m × 4 m, each consisting of four ridges spaced 60 cm apart. The treatments consisted of different population densities of jungle rice, which were introduced into the maize crop as follows:

D1: Control (no jungle rice)
D2: (5 plants m^{-2})
D3: (10 plants m^{-2})
D4: (15 plants m^{-2})
D5: (20 plants m^{-2})
D6: (25 plants m^{-2})

Crop establishment

Maize was sown in the last week of July at a seed rate of 25 kg ha^{-1}, equivalent to a population density of 66,666 plants ha^{-1}. Seeds were planted manually on the ridges, maintaining a row-to-row distance of 60 cm. A plant-to-plant spacing of 25 cm was ensured by thinning surplus plants after germination.

Fertilizer application

The nutrient requirements for the maize crop were met as follows:

Nitrogen (N): Urea was used to supply nitrogen at a rate of 120 kg ha^{-1}, which was applied in two equal splits half at the time of sowing and the other half at

25 days after sowing (DAS) during the first irrigation.
Phosphorus (P_2O_5): P_2O_5 was applied at 90 kg ha^{-1} as a basal dose via single superphosphate (SSP).
Potassium (K_2O): Supplied at 60 kg ha^{-1} as a basal dose via potassium sulfate.

Weed established

Jungle rice seeds were broadcast in the designated plots to achieve the specified population densities. Light irrigation was applied to facilitate uniform germination. Thinning was conducted to maintain the desired density levels for each treatment.

Data collection

The following parameters were recorded during the experiment.

1. Maize growth parameters:

- The plant height (cm) at maturity was measured via a meter rod.
- Plant height (cm) was measured at physiological maturity.
- The leaf area index (LAI) was calculated as the ratio of total leaf area to ground area.

2. Yield components and grain yield:

- Number of cobs per plant and grains per cob.
- The 1000-grain weight (g) was obtained by weighing one thousand seeds from each plot.
- The grain yield (t ha^{-1}) was calculated from the harvested grain weight and converted to tons per hectare.

3. Grain protein content:

- Fifty grams of maize seeds from each plot were ground to determine the nitrogen content via the Kjeldahl method. The nitrogen values were multiplied by 6.5 to estimate the protein content.

Statistical analysis

The data were analyzed via analysis of variance (ANOVA) (Steel *et al*., 1997). The treatment means were compared via the least significant difference (LSD) test at the 5% significance level. Statistical analyses were performed via "Statistix 8.1" software.

Irrigation and crop management

The crop was irrigated according to standard agronomic practices to ensure optimal growth. Regular monitoring was carried out to observe plant health, pest infestations, and environmental conditions throughout the growing season.

Results and Discussion

Plant population (m^{-2}), plant height (cm), number of cobs $plant^{-1}$ and number of grains cob^{-1}

The final maize plant population per unit area was significantly influenced by varying jungle rice densities, as shown in Table 1. Increasing weed density progressively reduced the maize population, with the maximum reduction (4.25 plants m^{-2}) observed at 25 jungle rice plants m^{-2}. Low weed densities (5, 10, 15, and 20 plants m^{-2}) resulted in reductions of 5.50, 5.50, 5.25, and 5.25 plants m^{-2}, respectively, which were statistically similar to those of the non-weed control (6.25 plants m^{-2}). These findings highlight the competitive ability of jungle rice, which is established quickly and monopolizes resources. Similar trends were reported by Paul *et al*. (2017) and Arif *et al*. (2010), who reported significant reductions in maize populations at relatively high weed densities and stressed the importance of timely weed management.

Maize plant height, a critical indicator of competition for light and nutrients, was also negatively affected by jungle rice density. At lower densities (5 and 10 plants m^{-2}), the plant heights were 179.50 cm and 175.75 cm, respectively, which were statistically comparable to those of the control (182.00 cm). However, higher densities caused significant reductions, with the shortest plants (153.75 cm) recorded at 25 jungle rice plants m^{-2}. Intermediate reductions were noted at 15 and 20 plants m^{-2}, producing heights of 167.50 cm and 163.00 cm, respectively. The reduced growth at relatively high weed densities reflects resource competition, as reported by Sarabi *et al*. (2013) and Khan *et al*. (2016), who reported similar trends in maize grown with competing weeds.

The number of cobs per plant, which is governed primarily by the genetic makeup of maize, remained unaffected by jungle rice density, as shown in Table 1. This consistency is attributed to the uniform hybrid maize variety used in the experiment. These findings align with those of Maqbool *et al*. (2016), who also reported nonsignificant effects of weed population on cobs per plant.

In contrast, the number of grains per cob significantly decreased with increasing jungle rice density. At lower densities (5 and 10 plants m^{-2}), the grain counts were 423.75 and 415.25 per cob, respectively, which were statistically comparable to those of the control

(429.00 grains per cob). However, higher densities caused substantial reductions, with the lowest grain count (311.50 per cob) recorded at 25 plants m^{-2}, followed by 342.00 grains per cob at 20 plants m^{-2}. These findings are consistent with the results of Saeed *et al.* (2012), who reported increased grain counts when weed densities were maintained within acceptable thresholds.

Competition from jungle rice limits nutrient availability for maize, particularly during the critical phase of nutrient translocation to seeds, necessitating additional fertilizer applications. Such interventions increase production costs and reduce profitability. Therefore, effective weed management is essential to minimize competition, sustain crop growth, and ensure optimal productivity.

Table 1: *Plant population (m^{-2}), plant height (cm), number of cobs plant^{-1} and number of grains (cob^{-1}) in maize affected by different jungle rice planting densities.*

Treatments	Plant population (m^{-2})	Plant height (cm) at maturity	Number of cobs (plant^{-1})	Number of grains (cob^{-1})
D1	6.25 a	182.00 a	1.25^{NS}	429.00 a
D2	5.50 a	179.50 a	1.25	423.75 a
D.3	5.50 a	175.75 ab	1.25	419.75 a
D4	5.25 ab	167.50 abc	1.00	390.25 ab
D5	5.25 ab	163.00 bc	1.00	342.00 bc
D6	4.25 b	153.75 c	1.00	311.50 c
$LSD_{0.05}$	2.16	15.49	----	70.00

Each column's mean values that have a similar letter or letters next to them are not significant.

1000-grain weight (g), grain yield (t ha^{-1}), leaf area index and grain protein content

The primary goal of farmers is to maximize grain yield, which is achievable through optimal agricultural practices and effective weed management. Table 2 shows that at lower jungle rice densities (5 and 10 plants m^{-2}), the maize yield was minimal, with values of 6.02 and 5.97 t ha^{-1}, respectively, which were statistically comparable to those of the non-weed control (6.25 t ha^{-1}).

Conversely, increasing the jungle rice density significantly reduced the grain yield. The lowest yield (2.52 t ha^{-1}) was recorded with 25 plants m^{-2}, whereas intermediate reductions occurred at densities of 20 and 15 plants m^{-2}, with yields of 3.42 and 4.40 t ha^{-1}, respectively. Higher yields at lower weed densities were attributed to improved crop conditions, including more grains per cob, more rows per cob, longer cobs, and greater 1000-grain weights. These results align with those of Saeed *et al.* (2012), who reported substantial yield variation due to weed competition. Maintaining jungle rice densities at or below 10 plants m^{-2} is critical for sustaining maize productivity.

The 1000-grain weight, a key yield parameter, was significantly affected by the jungle rice density. At 5 and 10 plants/m^2, the weights were 188.29 g and 181.86 g, respectively, which were statistically similar to those of the control (183.02 g). However, higher densities caused significant reductions, with the lowest weight (146.58 g) recorded at 25 plants/m^2. Intermediate reductions were observed at 20 and 15 plants m^{-2}, with weights of 151.18 g and 175.01 g, respectively. Low weed densities allow maize to assimilate sufficient nutrients and moisture, increasing grain weight. In contrast, higher densities increased competition, reducing nutrient transport and seed weight. Sinha (2004), Shehzad *et al.* (2013), and Imoloame and Omalaiye (2017) reported similar trends, emphasizing timely weed control to improve grain size and weight.

The leaf area index (Table 2) was also significantly influenced by the jungle rice density. At lower densities (5 and 10 plants m^{-2}), the index (4.25 and 4.12) was statistically similar to that of the non-weed control (4.37). However, higher densities significantly reduced the index, with the lowest value (0.75) observed at 25 plants/m^2. Intermediate reductions occurred at 20 and 15 plants m^{-2}, with values of 1.55 and 2.97, respectively. This decline was due to competition for light, nutrients, and water, which hindered maize development. El-Naim *et al.* (2010), and Shehzad *et al.* (2011, 2013) reported similar reductions in the leaf area index with increasing weed density.

The grain protein content in maize was unaffected by lower jungle rice densities (5–20 plants/m^2), with values of 9.97, 9.45, 9.10, and 8.92, respectively, which were statistically similar to those of the control (9.97). However, the highest weed density (25 plants m^{-2}) reduced the protein content to 8.67. This decline was likely due to nutrient competition, which negatively impacts both growth and quality. Ayeni and Kayode (2013) also reported that weed interference is a significant factor in reducing crop quality, with effects intensifying at relatively high densities.

Table 2: *Effects of different jungle rice planting densities on the 1000-grain weight (g), grain yield (t ha^{-1}), leaf area index and grain protein content of maize.*

Treat-ments	1000-grain weight (g)	Grain yield (t ha^{-1})	Leaf area index	Grain protein content
D1	183.02 a	6.25 a	4.37 a	9.97 a
D2	188.29 a	6.02 a	4.25 a	9.70 ab
D.3	184.24 a	5.97 a	4.12 a	9.45 ab
D4	175.01 b	4.40 b	2.97 b	9.10 ab
D5	151.18 c	3.42 c	1.55 c	8.92 ab
D6	146.58 c	2.52 d	0.75 c	8.72 b
$LSD_{0.05}$	7.59	0.65	0.94	1.19

Each column's mean values that have a similar letter or letters next to them are not significant.

Conclusions and Recommendations

In conclusion, varying densities of jungle rice significantly impacted maize growth and productivity, with lower densities (5 and 10 plants m^{-2}) having minimal effects on the plant population, height, cob count, and grain yield. However, as the jungle rice density increased, maize experienced notable reductions in these parameters, with the lowest values recorded at the highest density of 25 plants m^{-2}. Specifically, higher weed densities reduced plant height, 1000-grain weight, the leaf area index, and the grain protein content, underscoring the negative impact of weed competition for resources. Effective weed management, especially maintaining jungle rice densities below 10 plants m^{-2}, is crucial for optimizing maize growth, yield, and quality. Timely weed control can mitigate nutrient and moisture competition, thereby increasing maize productivity and profitability.

Novelty Statement

The manuscript is novel and has not been submitted/ published elsewhere.

Author's Contribution

Sheheryar: Collected data, did analysis, wrote the manuscript.
Iqtidar Hussain:Proof read the manuscript, supervised the whole study.

Conflict of interest
The authors have declared no conflict of interest.

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