The Pharma Innovation Journal 2023; 12(10): 1454-1456

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(10): 1454-1456

www.thepharmajournal.com
Received: 14-08-2023
Accepted: 21-09-2023

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Impact of pre-emergence and post-emergence herbicide in different combination for foremost weed control in chickpea (*Cicer arietinum* L.)

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Abstract
In the year 2022, a research study was conducted at the Agricultural Research Field of Sage University in Bhopal, focusing on Rabi crops. The experiment employed a randomized block design (RBD) with seven distinct treatments, each of which was replicated three times. These treatments included variations of two herbicides: pendimethalin (at rates of 0.40 and 0.60 kg a.i./ha) and imazethapyr (at rates of 40 and 60 g a.i./ha), both applied in pre- and post-emergence stages. Additionally, there were control groups, namely a weedy check and a weed-free treatment.
The most successful weed management strategy emerged from the sequential application of pre- and post-emergence herbicides, specifically pendimethalin at a rate of 0.60 kg a.i./ha (PE) and imazethapyr at 60 g a.i./ha at 20 days after sowing (DAS). This treatment demonstrated superiority over other weed management approaches, as it resulted in significantly higher seed yields, greater weed control efficiency, and a lower weed index. Interestingly, this treatment performed on par with the combination of pre- and post-emergence herbicides, which consisted of pendimethalin at 0.60 kg a.i./ha (PE) and imazethapyr at 40 g a.i./ha at 20 DAS (T_6) throughout all stages of crop growth.
While the weed-free treatment achieved the highest seed yield and exhibited significant effectiveness compared to other weed management strategies, it was statistically equivalent to the performance of treatment T_6.

Keywords: Chickpea, herbicide, weed control efficiency, weed index, yield

Introduction
India has established itself as a leading producer of Rabi pulse crops, with chickpea taking the forefront as the primary pulse crop. Chickpea cultivation in India spans across an impressive 84 million hectares, resulting in an annual yield of 8.32 million tonnes, with a productivity rate of 942 kg/ha during the 2016 to 2017 period. Notably, in the state of Madhya Pradesh, chickpea thrives in moist sub humid to dry sub humid, and ranks second in terms of land area dedicated to its cultivation, covering 1.26 million hectares. However, the productivity in Madhya Pradesh 2692.6 thousand ha with a production of 2474.6 thousand t remains relatively, averaging production 926 kg/ha.
Among the significant factors limiting chickpea yield, weed management stands out as a critical concern. Weeds possess a remarkable ability to outcompete crops for essential plant nutrients, thus posing a substantial threat to chickpea growth. Chickpea, characterized by slow early growth and a short stature, is particularly vulnerable to weed competition, which can result in staggering yield losses, sometimes reaching up to 75% (Chaudhary *et al*., 2005) [3]. The initial 60 days of chickpea cultivation are considered a crucial period for addressing weed-crop competition. Unfortunately, manual weed control has become increasingly challenging due to labor shortages and rising labor costs.
To address these challenges effectively and enhance chickpea cultivation, there is a growing need for suitable herbicides capable of managing mixed weed populations. Researchers have explored the efficacy of pendimethalin as a pre-emergence treatment at a rate of 1.0 kg/ha (Singh and Jain, 2017) [10] and its application at 80 g/ha for weed control (Patel *et al*., 2017) [14] in various regions across the country. These studies have reported effective control of annual broad-leaved and grassy weeds during the early stages of chickpea growth. However, it's worth noting that imazethapyr, while effective, can only be used for controlling later weed flushes as a post-emergence treatment (Rathod *et al*., 2017) [9].
Given these considerations, the present study aims to investigate the effectiveness of both pre and post-emergence herbicides in combating chickpea weeds, either individually or in combination with other weed management strategies.

2. Materials and Methods
2.1 Experimental site
The research study was conducted at the Agriculture Research Farm of Sage University, Bhopal, situated geographically between 23.18' North latitude and 77.52' East longitude. This location has an elevation of 457 meters above mean sea level. The region falls within the agro-climatic zone Ia, classified as "Moist sub-humid," within the state of Madhya Pradesh.

2.2 Experimental site and treatments
In the Rabi season of 2022, a field experiment was conducted at the Agricultural Research Field of Sage University, Bhopal. The experiment was structured using a randomized block design (RBD) and included seven treatment combinations, namely:
1. W1 - Weedy Check
2. W2 - Weed Free
3. W3 - Pendimethalin @ 0.60 kg a.i./ha (PE)
4. W4 - Imazethapyr @ 60 g a.i./ha at 20 DAS
5. W5 - Pendimethalin @ 0.30 kg a.i./ha (PE) + Imazethapyr @ 30 g a.i./ha at 20 DAS
6. W6 - Pendimethalin @ 0.40 kg a.i./ha (PE) + Imazethapyr @ 60 g a.i./ha at 20 DAS
7. W7 - Pendimethalin @ 0.60 kg a.i./ha (PE) + Imazethapyr @ 40 g a.i./ha at 20 DAS

Each treatment was replicated three times. In this experiment, pendimethalin was applied as a pre-emergence treatment within the first three days after sowing (DAS), while imazethapyr was applied as a post-emergence treatment at 20 DAS. Chickpea seeds were manually sown with a row spacing of 30 cm and at a seeding rate of 60 kg/ha. Nitrogen (20 kg/ha) and phosphorous (40 kg/ha) were uniformly applied using urea and DAP, respectively, during field preparation.
The herbicides were applied using knapsack sprayers equipped with flat fan nozzles according to the respective treatment requirements. Standard agricultural practices were followed to manage the crop as recommended. Immediately after sowing, a light irrigation was provided to ensure uniform germination, and the pre-emergence herbicides were applied on the following day. Observations were recorded randomly within 0.50 m^2 quadrants in the designated plot area for parameters such as the number of weeds and the dry matter of weeds. Weed control efficiency was calculated using the formula suggested by Mani *et al*. (1973) [7]. Seed and stalk yields were harvested from the designated plot area and extrapolated to hectare-level measurements for comparative analysis.

3. Results and Discussion
3.1 Effect of pre and post-emergence herbicides on weed control efficiency
The effectiveness of weed control measures clearly demonstrated that herbicides outperformed the weedy check in managing weed growth. The data presented in Table 1 revealed that the highest levels of weed control efficiency were achieved through the sequential application of pre and post-emergence herbicides, specifically pendimethalin at a rate of 0.30 kg a.i./ha (PE) combined with imazethapyr at 30 g a.i./ha at 20 DAS (T_5). This was closely followed by the treatment involving pendimethalin at 0.60 kg a.i./ha (PE) combined with imazethapyr at 40 g a.i./ha at 20 DAS (T_6). These treatments consistently exhibited the highest levels of effectiveness, reaching 95.33% and 94.41%, respectively, at the 90-day mark.
The superior performance of pendimethalin and imazethapyr combinations can be attributed to their broad-spectrum nature, effectively inhibiting weed growth by interfering with essential cellular processes such as cell division and elongation. Imazethapyr, in particular, acts as an inhibitor of three branched-chain amino acids in weeds, leading to reduced weed counts and dry weight, as suggested by Das in 2015 [4]. This underscores the promise of imazethapyr as an effective option for reducing weed density and inhibiting dry matter accumulation.

3.2 Impact of pre and post-development herbicides on weed record
The impact of weed competition on crop yield, as compared to weed-free conditions, is quantified using a metric known as the weed index. Table 2 presents the yield reduction attributed to weeds in each treatment when contrasted with a weed-free plot. The effectiveness of different weed management treatments varied in their ability to mitigate this yield reduction.
Among the treatments, it was observed that the combination of pendimethalin at 0.60 kg a.i./ha (PE) and imazethapyr at 40 g a.i./ha at 20 DAS (W7), followed closely by the treatment involving pendimethalin at 0.40 kg a.i./ha (PE) and imazethapyr at 60 g a.i./ha at 20 DAS (W6), resulted in the least yield losses when compared to the weed-free plot. On the contrary, the weedy check (W1), plagued by a heavy weed infestation, exhibited the most significant yield loss as indicated by the weed index. Additionally, the application of pendimethalin and imazethapyr as standalone treatments also contributed to reduced yield due to their comparatively lower efficacy in weed control, especially when compared to their combined application as pre and post-emergence herbicides.
These findings align with the research conducted by Chandrakar *et al*. (2015) [2] and Singh *et al*. (2014) [11], underscoring the importance of integrated weed management strategies for optimizing crop yield while minimizing the adverse effects of weed competition.

3.3 Impact of pre and post-development herbicides on yield
Seed yield serves as a pivotal parameter for assessing the effectiveness and superiority of various treatments, as illustrated in Table 2. Notably, the treatments involving pendimethalin at 0.60 kg a.i./ha (PE) in combination with imazethapyr at 40 g a.i./ha at 20 DAS (W7) and pendimethalin at 0.40 kg a.i./ha (PE) paired with imazethapyr at 60 g a.i./ha at 20 DAS (W6) demonstrated significantly higher seed yields in comparison to the other weed management approaches, yielding 2320.10 and 2226.51 units, respectively. The relatively minor differences observed between the W2 and W7 treatments may be attributed to the consistent control of weeds throughout the entire period of seed development. In such circumstances, the reduced weed competition allows for a more efficient photosynthetic process, enhancing the seed production ratio significantly. These findings are consistent with the findings of a previous study conducted by Dubay *et al*. (2018) [5].
Furthermore, a negative correlation with a correlation coefficient of 1.00 was established between the weed index

and seed yield. This correlation was further corroborated through regression analysis, which revealed a decrease of 23.260 kg/ha in chickpea seed yield as weed density and dry weight increased, as indicated by the weed index. These results underscore the detrimental impact of weed competition on chickpea seed yield and highlight the importance of effective weed management practices in optimizing crop productivity.

Table1: Weed control efficiency as influenced by various weed management treatment

Treatment	30 DAS	60 DAS	90 DAS	At Harvest
W1	0.00	0.00	0.00	0.00
W2	100.00	100.00	100.00	100.00
W3	69.05	70.18	79.52	65.35
W4	71.43	61.40	73.24	58.60
W5	78.57	85.92	91.07	89.18
W6	83.33	87.80	91.94	90.61
W7	85.61	90.62	94.21	93.10

Table 2: Seed yield of chickpea and weed index as influenced by various weed management treatments

Treatment	Seed yield (kg/ha)	Weed index (%)
W1	727.10	67.21
W2	2320.10	0.00
W3	1602.13	30.24
W4	1479.13	35.87
W5	1990.81	14.21
W6	2075.38	10.24
W7	2226.51	4.03

4. Conclusion

The combined application of pendimethalin at 0.60 kg a.i./ha (PE) and imazethapyr at 40 g a.i./ha at 20 DAS demonstrated a notable impact on weed control efficiency, weed index reduction, and the attainment of maximum chickpea grain yield. However, it's worth noting that its effectiveness was on par with the treatment involving pendimethalin at 0.40 kg a.i./ha (PE) in combination with imazethapyr at 60 g a.i./ha as both pre- and post-emergence herbicides applied at 20 DAS (W6). These findings are derived from a single year of experimentation, and to provide a more robust recommendation, further research and experimentation are required for validation.

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