Original Research Article

Evaluationof the Impact of Herbicidal Weed Management Practices on Yield Attributes and Yield of irrigated Chickpea (*Cicer arietinum* L.)

Abstract: In the *Rabi* season of 2021-22, an experiment was conducted at the Agronomy Research Farm of CCS Haryana Agricultural University in Hisar. The aim was to examine how herbicidal weed management affects irrigated chickpea. The experiment was laid out in Randomised Block Design (RBD) with thirteen treatments, each repeated three times. The treatments included various herbicides applied at different stages, such as pre-plant incorporation (PPI), pre-emergence (PRE), and post-emergence (POE). Interestingly, the Ready mix (RM) herbicide application of pendimethalin + imazethapyr (RM) @ 1000 g a.i ha^{-1}, applied both as PPI and PRE, outperformed the herbicides applied solely as PPI, PRE, or POE. Among the herbicidal treatments, the combined during PPI and PRE stages exhibited excellent control over a diverse weed population, leading to a significant increase in chickpea yield compared to the weedy check. The number of seeds per pod, pods per plant, and branches per plant varied significantly with different weed control treatments. Weed-free plots showed the highest values in these parameters. The uncontrolled growth of weeds in the weedy check resulted in a 55.2% reduction in seed yield as compared to weed-free plots. The maximum seed yield (1968 kg ha^{-1}) and favorable yield attributes were observed in the weed-free treatment, statistically comparable to the yield obtained from two hand weeding at 30 and 50 days after sowing (1940 kg ha^{-1}). Among herbicidal treatments, the highest seed yield was achieved with the PRE application of pendimethalin + imazethapyr (RM) @ 1000 g ha^{-1} (1827 kg ha^{-1}). The dominant weed flora consisted of *Chenopodium album*, *Fumaria parviflora* and *Anagallis arvensis*. Density of different weed species was significantly influenced by different weed control treatments. All the weed control treatments significantly reduced the total weed density and dry matter accumulation by weeds in comparison to weedy check**.** Weed free and two hand hoeing reduced the weed population drastically which was statistically at par with PRE application of pendimethalin + imazethapyr (RM) at 1000 g ha^{-1}. *Chenopodium album*, *Fumaria parviflora* and *Anagallis arvensis* were effectively controlled by RM irrespective of its time of application.

Keywords: *Chickpea; Imazethapyr; Pendimethalin; Growth attributes; Yield*

1. INTRODUCTION

Pulses have been a fundamental part of the human diet since ancient times and are among the most widely consumed food crops globally. They are highly adaptable to various soil and environmental conditions, making them essential for mitigating the adverse effects of climate change (Singh *et al*., 2020). These legumes are not only nutritious but are also often referred to as the "poor man's meat" due to their high protein content (Mohanty and Satyasai, 2015). India's primary pulses include chickpea, dry bean (such as mung bean, urd bean, moth bean, and red kidney bean), pigeon pea, lentils, and dry peas. Chickpea, scientifically known as *Cicer arietinum* L., is a self-pollinating legume crop belonging to the Leguminosae family. India leads the world in both chickpea production and consumption, with an average yield of approximately 11.9 million tons grown across 8.8 million hectares and a national productivity rate of 1.11 tons per hectare (Anonymous, 2022). The major chickpea-producing states, in descending order, are Madhya Pradesh, Maharashtra, Uttar Pradesh, Rajasthan, and Andhra Pradesh. Chickpea seeds aremainly composed of carbohydrates and protein, accounting for about 80 percent of their total dry seed mass. Chickpea offers superior protein quality compared to other pulses and can reduce the risk of heart disease due to the presence of saponin. Moreover, germinated chickpea seeds are believed to have curative properties for scurvy. Remarkably, chickpea contains more carotenoids than genetically modified golden rice (Mallikarjuna *et al*., 2007) and is also used as fodder and green manure (Erman *et al.*, 2011). Additionally, under suitable management conditions, chickpea can fix up to 141 kg of nitrogen per hectare per year through its symbiotic relationship with *rhizobium*, meeting 80 percent of its nitrogen requirements (Herridge *et al*., 1995). The significance of chickpea in human and animal diets is attributed to its high concentrations of protein (19.3-25.4%), carbohydrates (52-70%), fat (4-10%), minerals (such as calcium, phosphorous, and iron), vitamins (particularly niacin), and trace elements (Yadav *et al*., 2007; Hassan and Khan, 2007). Chickpea is classified into two main categories primarily based on seed characteristics. The 'Desi' types, characterized by relatively small, angular seeds with a typically rough, yellow to dark brown testa, make up approximately 85% of the global annual production. These are mainly found in the Indian subcontinent, Ethiopia, Mexico, and Iran. On the other hand, the 'Kabuli' types, distinguished by larger, more rounded, and cream-colored seeds, represent a minor portion of both area and production. However, they are predominant in crops across Europe and the Americas, excluding Mexico.

Among the various factors limiting chickpea yields, weeds pose a significant challenge. Chickpea, being a short-stature crop with slow initial growth and limited leaf area development, is highly susceptible to weed infestation. Weeds have become such a menace that effective weed management practices are now essential. The presence of weeds throughout the crop season can reduce chickpea seed yields by up to 68 percent. Some of the major weeds in chickpea include *Chenopodium album*, *Fumaria parviflora*, and *Phalaris minor*, along with other minor weed species like *Convolvulus arvensis*, *Anagallis arvensis*, *Melilotus alba*, *Coronopusdidymus*, and *Spergula arvensis*. The yield loss in chickpea due to weed interference ranges from 40 to 90 percent. Punia *et al*. (2015) stated that the primary weeds in Haryana include *Asphodelus tenuifolius*, *Chenopodium album*, *Trigonella polycerata*, *Chenopodium murale*, *Convolvulus arvensis*, and *Euphorbia dracunculodes*. According to Kumar *et al*. (2014), the continuous presence of weeds throughout the crop season can lead to a significant reduction in chickpea seed yield, reaching up to 68 percent. The first 60 days are crucial for crop-weed competition, as highlighted by Singh and Singh (1992).While it is ideal to maintain a weed-free crop throughout the growing season to minimize competition and losses, it is not economically viable. Various weed control methods, including mechanical, manual, cultural, and chemical approaches, exist. Less developed farming systems commonly employ mechanical and manual methods, whereas developed farming systems favor cultural and chemical methods. Farmers often opt for manual weeding, a labor-intensive and costly process. During the peak crop period, the expenses for manual weeding significantly rise, and agricultural laborers may migrate to industries seeking better and more stable wages. This migration makes achieving complete weed control through manual weeding challenging in the later growth stages of chickpeas. To combat weed issues, herbicides like pendimethalin, belonging to the dinitroaniline class, are used as pre-emergence (PRE) and post-emergence (POE) treatments to control a wide range of weeds. Imidazolinone herbicides provide effective control of weeds in chickpea fields, especially in the early stages. Pendimethalin applied as a PRE treatment at 1.0 kg per hectare effectively controls annual broad-leaved and grassy weeds, while imazethapyr is necessary as a POE treatment for later weed flushes. Chickpea, known for its slow initial growth and short stature, face a high vulnerability to weed competition, resulting in significant yield losses of up to 75% (Chaudhary *et al*., 2005). Weeds tend to emerge early and grow rapidly, leading to intense competition with chickpea for light, moisture, nutrients, and space. Traditionally, farmers have relied on manual weeding to control weeds, but rising labor costs and labor shortages have made this method challenging for chickpea cultivation. Effective weed control during the early stages of chickpea growth is crucial, as this is when crop-weed competition is most severe. Within the first 30 days of sowing, chickpea grain yield can decrease by 17.1% due to weed competition, and this loss can escalate to approximately 50% when weeds compete with the crop throughout the entire growing season. The initial 60 days are considered a critical period for weed-crop competition in chickpea (Singh and Singh, 1992). To address this issue, the need for a suitable herbicide to efficiently manage a variety of weeds in chickpea cultivation has become evident. Herbicides have proven effective in controlling a wide range of weeds in pulse crops at a reasonable cost.

To control flushes of weeds, the adoption of pre and post-emergence herbicides can be a viable option. Herbicides play an important role in controlling a wide variety of weeds and the ones presently in use are pendimethalin, oxyfluorfen, Imazethapyr, fluchloralin etc. To avoid crop weed competition in the early stages, the application of pre-emergence (PRE) herbicides becomes necessary. Pendimethalin belongs to the class of dinitroaniline and is used as PRE and post-emergence (POE) to control a wide variety of weeds. It suppresses cell division and cell elongation. Imazethapyr is a comparatively new herbicide that belongs to the group of imidazolinone and is registered for use in many legume crops (Herbicide Handbook, USA, 2002). Application of pendimethalin as PRE at 1.0 kg ha^{-1} (Singh and Jain, 2017) provided effective control of annual broad-leaved and grassy weeds in chickpea fields at early stages. The later flushes of weeds can only be controlled by the application of imazethapyr as POE (Rathod *et al*., 2017). To control flushes of weeds throughout the crop growth period, a combined application of PRE and POE herbicides is required. The imidazolinone class of herbicides provides a broad spectrum of weed control activity as reported by Kantar *et al.* (1999). Sondhia*et al*. (2018) reported a higher grain yield of chickpea under pendimethalin application as compared to no weeding practice. The application of a ready mix (RM) of pendimethalin plus imazethapyr as PRE at 1000 g ha^{-1} and RM of Imazethapyr plus imazamox as POE at 80 g ha^{-1} provided the highest weed control in black gram (Gupta *et al*., 2017). Similarly, the application of pendimethalin 30% EC plus imazethapyr 2% SL (RM) at 960 g ha^{-1} recorded the highest weed control efficiency in soybean crops (Meena *et al*., 2018). Efficient management of weeds can lead to optimal utilization of the available resources which can in turn ensure a good yield of chickpea.

2. MATERIAL AND METHODS

2.1 Experimental Site: The experiment was conducted in the Crop Physiology laboratory area of Agronomy Research Farm, Chaudhary Charan Singh Haryana Agricultural University, Hisar, took place in the *Rabi* season of 2021-22. Throughout this season, the average weekly meteorological data was documented at the meteorological observatory situated on the CCSHAU Research Farm.

2.2 Climatic conditions: The experimental site is positioned at 29º 10´ N latitude and 75º 46´ E longitude, with an elevation of 215.2 m above mean sea level in the Haryana State of India. Hisar experiences a typical semi-arid and sub-tropical climate characterized by hot, dry winds in the summer and intense cold during the winter. In May and June, the maximum temperature can soar to approximately 48°C, while in December and January; the minimum temperature may drop below freezing. The region receives an average annual rainfall of about 450 mm, with 70-80 percent occurring during the monsoon period from July to September, and the remainder in sporadic rains throughout the rest of the year. From July to March, the mean relative humidity ranges from 75 to 90%, gradually decreasing in April and maintaining levels of 40-50% in the hot summer months of May and June. Morning hours exhibit higher relative humidity compared to the evening hours.

2.3 Soil Characteristics: The soil texture in the experimental area was sandy loam, with organic carbon content at 0.5%, available N at 113 kg ha^{-1}, available P at 11.7 kg ha^{-1}, available K at 252 kg ha^{-1}, and a pH of 8.1.

2.4 Experimental Details: The field experiment was laid out in randomized block design with three replications and 13 treatments. The allocation of these treatments in the field was done randomly using a random number table. The chickpea variety used was HC-6, and each plot measured 5 m in length and 4.5 m in width. The 13 treatments combinations are as follows: T_1 (Pendimethalin 30EC @ 1000 g a.i ha^{-1} applied as Pre-Plant Incorporation), T_2 (Imazethapyr 10EC @ 75 g a.i ha^{-1} applied as Pre-Plant Incorporation), T_3 (Imazethapyr 10EC @ 100 g a.i ha^{-1} applied as Pre-Plant Incorporation), T_4 (Pendimethalin 30EC + Imazethapyr 2% EC (Ready mix RM) @ 1000 g a.i ha^{-1} applied as Pre-Plant Incorporation), T_5 (Pendimethalin 30EC @ 1000 g a.i ha^{-1} applied as Pre-Emergence), T6 (Imazethapyr 10EC @ 75 g a.i ha^{-1} applied as Pre-Emergence), T_7 (Imazethapyr 10EC @ 100 g a.i ha^{-1} applied as Pre-Emergence), T_8 (Pendimethalin 30EC + Imazethapyr 2EC (RM) @ 1000 g a.i ha^{-1} applied as Pre-Emergence), T_9 (Imazethapyr 10EC @ 75 g a.i ha^{-1} applied as Post-Emergence), T_{10} (Imazethapyr 10EC @ 100 g a.i ha^{-1} applied as Post-Emergence), T_{11} (Two hand hoeing at 30 & 50 DAS), T_{12} (weed-free), and T_{13} (weedy check).

2.5 Agronomical Practices adopted: In the final week of October 2021, the experimental site was meticulously prepared. To break up clods, the field underwent two rounds of plowing using a tractor-drawn cultivator, and any residues from the previous crop were cleared. Cross harrowing and two additional passes with a cultivator were followed by planking to create a finely tilled soil before sowing. A standardized basal dose of fertilizers, consisting of 20 kg ha^{-1} nitrogen and 40 kg ha^{-1} phosphorous through DAP, was applied during field preparation. Following the planned layout, the crop was sown using the *pora* method on the well-prepared field on October 30, 2021.Herbicides were applied using a knapsack sprayer, ensuring sufficient soil moisture during application. Approximately 55 days after chickpea sowing, a light irrigation was applied on December 25, 2021. The treatment plot (T_{12}) was kept weed-free throughout the crop's growth by manual hand weeding. Two hoeings were performed at 30 and 50 days after sowing in the treatment plot (T_{11}) using a hand hoes, maintaining the recommended spacing and a weed-free environment. The experimental area showed no severe instances of insect pests or diseases, and the plant stand remained satisfactory, eliminating the need for additional plant protection measures. To determine the total number of branches per plant, the count was conducted during the harvest stage for five randomly selected plants in all treatments. The average of the branch count for these five plants was then recorded as the number of branches per plant. At full physiological maturity, the chickpea crop was harvested using a sickle, cutting close to the ground in each plot separately. The harvested produce was sun-dried in the respective plot until a constant weight was achieved. After drying, bundles of produce were formed for each plot, and their weights were recorded. Subsequently, the crop was hand-threshed, and the seed weight of each plot was measured in kg plot^{-1} and later calculated to kg ha^{-1}.

2.6 Statistical analysis: The allocation of different treatments in the plot was allotted as per design. The data recorded on different growth characters, yield attributes, and grain yield during the investigation was subjected to statistical analysis of variance techniques in a Randomized Block Design (RBD)as detailed by Gomez and Gomez, 1984.This analysis aimed to determine any significant disparities among the treatment averages. To assess these differences, the Least Significant Difference (LSD) test was employed at a significance level of 5%.

3 Results and discussion

3.1 Weed studies: The composition and prevalence of weed flora in cultivated areas primarily hinge on the soil type and climatic conditions of the region, in addition to the influence of cultural practices implemented within the specific cropping system over the years. A plant's growth at any developmental stage is shaped not only by its genetic makeup but also by the environmental conditions in which it matures. Consequently, factors such as temperature, rainfall, and humidity during the crop season play a pivotal role in influencing growth, development, and ultimately, grain yield. These weather conditions serve as a critical indicator for determining the final crop yield and were generally consistent with the average conditions of the locality. It can be asserted that the soil and weather conditions were uniform across all treatments, and any observed variations under different treatments were predominantly attributable to the effects of the treatments rather than variations in soil and climatic factors. Thus, the fluctuations noted in different treatments were primarily a result of the treatment effects rather than other contributing factors.The effect of different herbicidal treatments on weed flora was studied in terms of total weed density (No. m^{-2}) at 30, 60, 90, 120 DAS and at maturity. The data recorded on density of associated weeds as influenced by various weed control treatments are presented in Table 1. The comparison among the treatment means have been made on transformed values in case of weed parameters only. The experimental field was mainly infested with *Chenopodium album*, *Anagallis arvensis*, *Fumaria parviflora* and other miscellaneous weed species in low density. Almost similar floristic composition of weeds in chickpea was reported by Sharma (2009), Khope*et al.*

(2011), Singh and Jain (2017). Highest population of different weeds was recorded in case of weedy check at all the growth stages, as weed growth was luxuriant and uninterrupted in the absence of any weed control practice throughout the crop growing season and it was significantly higher over other weed control treatments (Table 1). Two hand hoeing employed at 30 and 50 DAS in chickpea proved effective in minimizing the weed density and dry weight and resulted in maximum weed control efficiency at all the stages of crop growth. These results corroborate with the findings of Chandrakar*et al*. (2015) and Kumar *et al*. (2014). All the weed control treatments reduced the population of weeds significantly in comparison to weedy check (Table 1).

PRE application of pendimethalin + imazethapyr (RM) @ 1000 g ha^{-1} provided more effective control of all types of weeds. There was significant reduction in total weed density due to RM herbicides mixture as compared to application of pendimethalin as PPI and PRE and imazethapyr as PPI, PRE and POE. PRE application of pendimethalin + imazethapyr (RM) had distinct advantage over POE imazethapyr because of the better weed control early in the crop growth season. Mathukia*et al*. (2017) reported comparable findings. The practice of hand weeding, conducted twice at 20 and 40 days after sowing (DAS), resulted in the most significant reduction in weed density compared to herbicidal treatments. This substantial decrease was attributed to the thorough elimination of various weed types throughout the hand weeding process. Similar perspectives were also affirmed by Sharma and Singh (2005), who observed minimal weed density under the hand weeding treatment, emphasizing the elimination of all weed types during the weeding process.

3.2 Yield attributes: The traits contributing to yield, specifically pods per plant exhibited superior performance in plots subjected to two hand weeding sessions compared to the weedy check. However, the seed weight remained largely consistent across all treatments (see Table 2). The remarkable growth and development of chickpea plants in a weed-free environment during the critical period of crop growth likely contributed to the superior yield attributes observed under the hand weeding treatment in contrast to the weedy check, which experienced intense weed competition from early growth stages, leading to markedly inferior yield attributes. The application of RM as a pre-emergence herbicide @ 1000 g a.i ha^{-1} resulted in improved yield-contributing characteristics (pods per plant) compared to dole application of same herbicides, such as pendimethalin (30 EC) as a pre-plant incorporated herbicide @ 1000 g a.i ha^{-1} and imazethapyr (10 EC) as a post-emergence herbicide @ 75 g a.i ha^{-1} and 100 g a.i ha^{-1}. Complete data analysis revealed a significant variation in the pods/plant). Pre-emergence application of RM led to a notably greater number of pods per plant (40.48) compared to the weedy check treatment (26.77). Nevertheless, hand weeding showed the highest pods per plant (42.97) among all weed control treatments which was likely attributed to its superior weed control efficiency and the accelerated growth rate of the crop under this treatment. Similar results were reported by Rathod *et al*. (2017) and Gore *et al*. (2015).

Among the various treatments, weed free recorded higher value of this yield attribute which was statistically at par with two hand hoeing performed at 30 and 50 DAS (Table 1). The hand weeding treatment recorded higher branches/plants, as indicated in Table 1.

Additionally, among the herbicidal treatments, T_8 and T_{12} demonstrated the highest number of branches per plant (8.87) which produced 97.1% higher number of branches per plant over weedy check treatment. The presence of a weed-free environment around individual plants created more favourable conditions for development, leading to superior branch expression compared to other treatments. The weedy check treatment, as observed, resulted in the minimum branches per plant, aligning with similar findings reported by Poonia and Pithia (2013), Kumar *et al*. (2014) and Dewangan*et al*. (2016).

3.3 Yield: Seed yield under specific treatments is a culmination of a complex process influenced not only by the genetic makeup of crop plants but also by the adopted production technology. Weeds can cause significant harm to crops, depending on factors such as the weed species present, their relative density, and the duration of crop-weed competition. The cumulative impact of these factors manifests as reduced crop yield. The efficiency and superiority of a particular treatment are often determined by the seed yield, a crucial parameter. The seed yield exhibited significant variation across different weed control treatments, as indicated in Table 1. Data presented in Table 1 shows that all weed control treatments significantly increased the seed yield over weedy check. In plots with no weed control (weedy check), the seed yield was at its lowest (880 kg/ha) due to intense competition stress from the establishment of the crop up to the critical period of crop growth. This stress led to suboptimal growth parameters, yield-contributing traits, and ultimately, the minimum seed yield (refer to Table 2). All treated plots, whether subjected to manual weeding or herbicidal treatments, demonstrated higher yields compared to the weedy check. The crops in hand-weeded plots experienced robust growth due to the elimination of weeds from both inter and intra rows. This created a favorable environment with enhanced aeration, manipulating surface soil for more available space, water, light, and nutrients, ultimately contributing to superior growth and development. These favorable conditions resulted in outstanding yield attributes and, consequently, the highest yield, as documented by Chandrakar*et al*. (2015). Similar findings supporting the effectiveness of hand weeding for achieving maximum chickpea yield were reported by Singh and Sahu (1996), Sharma and Singh (2005), and Chaudhary *et al*. (2005).

Lowest yield was recorded under weedy check due to abundant growth of weeds that competes efficiently with crop for moisture, nutrient, space and sunlight. Weed free plot recorded highest seed yield (1968 kg ha^{-1}) which was statistically at par with two hand hoeing employed at 30 and 50 DAS (1940 kg ha^{-1}). Similar results were obtained by Pedde *et al*. (2013), Poonia and Pithia (2013) in chickpea crop. The pre-emergence application of the RM resulted in a significantly higher seed yield of 1827 kg/ha compared to other weed management treatments. Similar results were obtained by Gupta *et al*. (2017). Most effective herbicide treatment i.e. PRE application of pendimethalin + imazethapyr (RM) at 1000 g ha^{-1} recorded 107.6% higher seed yield in comparison to weedy check treatment. Statistically similar results were obtained with PPI application of pendimethalin + imazethapyr (RM) at 1000 g ha^{-1}. The superiority of said treatments might be due to the prolonged persistence of herbicides which provided weed free conditions. The post emergence application of imazethapyr treatment showed the lowest seed yield. However, the hand-weeding treatment demonstrated the highest seed yield. The increased yields under hand weeding can be attributed to the early removal of weeds from the crop, minimizing crop-weed competition and creating a weed-free environment, as suggested by Yadav *et al*. (2019), (Bankoti*et al*., 2021). Higher yield attributes coupled with higher dry matter recorded under RM treatments might be the probable reason for higher seed yield. Similar findings were reported by Gupta *et al*. (2017). Therefore, the cumulative influence of growth as well as yield attributes ultimately increased the seed as well as biological yield of chickpea. The seed yield was found highest in weed free followed by two hand hoeing. Similar findings were also reported by Pedde *et al*. (2013). Weedy produced 55 per cent lower seed yield as compared to weed free which was attributed to the 38, and 39 per cent fewer number of pods per plant and seeds per pod over weed free. Moreover, better development of crop plants and higher weed control efficiency in weed free treatment also contributed to the increase in seed yield as compared to weedy, which was having the highest weed intensity and dry weight of weeds. All the herbicide irrespective of the time and dose of application produced significantly lower seed yield as compared to weed free. Similar results were reported by Mishra *et al*. (2005), Abhishek *et al*. (2019) and Koushik *et al*. (2014). Imazethapyr applied @ 100 g ha^{-1} as PPI and PRE produced 83 and 95 per cent higher grain yield as compared to its application as POE which might be due to the higher number of pods per plant (64% and 68%). Imazethpyr applied @ 75 or 100 g ha^{-1} as POE resulted in lower grain yield as compared to pendimethalin or RM treatments. This might be due to the phytotoxic effect of imazethapyr on chickpea crop plant which reduced the overall growth and the development of chickpea as clearly evident from lower values of LAI, dry matter accumulation and the various yield attributes. The lowest seed yield of chickpea was reported in imazethapyr treated plots (POE) @ 75 and 100 g ha^{-1}, which was 61 to 62 % lower than weed free, which was due to change in the plant architecture which ultimately led to reductions in the plant population.Amongst herbicidal treatments, PRE application of pendimethalin + imazethapyr (RM) at 1000 g ha^{-1} recorded significantly higher straw yield over rest of the treatments. The positive response of this yield attribute to different weed control treatments except POE application of imazethapyr could be ascribed to the overall increment in crop growth recorded at different growth stages especially dry matter production of chickpea. Reduction in crop-weed competition under RM treatments saved a substantial amount of nutrients for crop which led to accelerated growth of crop, enabling it to utilize more soil moisture and nutrients. These results were in accordance with the findings of Ratnam *et al*. (2011), Pritam *et al*. (2015) and Singh and Jain (2017). All these favourable effects resulted in significant increase in various yield determining characters of chickpea by improving the source-sink relationship (Tiwari *et al*., 2019). Weed free and two hand hoeing being at par with each other recorded the highest straw yield which was 100 and 98% higher over weedy. This might be due to higher dry matter accumulation and luxurious growth in the chickpea plant under weed free condition. Imazethapyr applied @ 100 g ha^{-1} as PPI and PRE recorded 88 and 89 per cent higher straw yield than its application as POE. This was due to effective control of weeds by the doses of imazethapyr applied at PPI and PRE resulting in better plant growth and ultimately the higher straw yield. Imazethapyr applied @ 75 or 100 g ha^{-1} as POE recorded no significant difference in straw yield and produced lower straw yield than pendimethalin treated plots, this was might be due to the phytotoxic effect of imazethapyr on chickpea plant at initial stages of crop growth resulting into stunted growth and reduced leaf size of chickpea. HI was unaffected due to various weed management practices in chickpea.

Table 1: Effect of weed control treatments on weed density (No. m-2) of Chenopodium album, Fumaria parvifora

Treatment	*Chenopodium album* (No. m^{-2})					*Fumaria parvifora*(No. m^{-2})				
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**Maturity**	**30 DAS**	**60 DAS**	**90 DAS**	**120 DAS**	**Maturity**
T_1	4.01 (15.10)	4.83 (22.33)	4.40 (18.37)	4.02 (15.20)	3.74 (12.99)	3.76 (13.17)	4.28 (17.33)	4.35 (17.90)	3.65 (12.33)	3.40 (10.57)
T_2	4.55 (19.70)	5.65 (30.90)	5.12 (25.2)	4.86 (22.57)	4.54 (19.65)	3.89 (14.13)	4.72 (21.30)	4.49 (19.13)	4.14 (16.17)	3.91 (14.27)
T_3	4.40 (18.34)	5.38 (27.93)	4.91 (23.10)	4.61 (20.23)	3.36 (12.01)	3.79 (13.33)	4.68 (20.93)	4.73 (21.40)	4.27 (17.20)	4.06 (15.47)
T_4	3.65 (12.36)	4.62 (20.41)	4.11 (15.87)	3.64 (12.27)	3.17 (9.09)	3.03 (8.20)	3.67 (12.47)	3.32 (10.03)	2.88 (7.33)	2.52 (5.43)
T_5	4.10 (15.80)	4.79 (22.01)	4.40 (18.37)	3.98 (14.83)	3.57 (11.78)	3.72 (12.87)	4.24 (16.93)	4.26 (17.17)	3.62 (12.13)	3.39 (10.50)
T_6	4.61 (20.23)	5.68 (31.30)	5.15 (25.53)	4.70 (21.06)	4.36 (18.06)	3.90 (14.20)	4.69 (21.03)	4.47 (18.97)	4.17 (16.40)	3.93 (14.43)
T_7	4.37 (18.14)	5.34 (27.47)	4.94 (23.37)	4.63 (20.43)	4.29 (17.43)	3.76 (13.17)	4.74 (21.43)	4.74 (21.43)	4.30 (17.50)	4.09 (15.70)
T_8	3.66 (12.39)	4.73 (21.40)	4.01 (15.12)	3.66 (12.40)	3.18 (9.15)	3.05 (8.33)	3.69 (12.63)	3.29 (9.83)	2.82 (6.93)	2.48 (5.17)
T_9	7.19 (50.70)	5.14 (25.37)	4.67 (20.84)	4.41 (18.47)	4.06 (15.47)	6.13 (36.60)	4.37 (18.07)	4.10 (15.80)	4.02 (15.17)	3.78 (13.27)
T_{10}	7.14 (49.98)	5.13 (25.34)	4.62 (20.34)	4.39 (18.30)	4.06 (15.54)	6.04 (35.42)	4.34 (17.80)	4.16 (16.33)	4.00 (15.00)	3.76 (13.10)
T_{11}	1.00 (0.00)	1.64 (1.70)	2.09 (3.39)	2.27 (4.13)	1.50 (1.24)	1.00 (0.00)	1.80 (2.27)	2.12 (3.50)	2.52 (5.34)	2.09 (3.37)
T_{12}	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_{13}	7.20 (50.83)	7.52 (55.64)	7.07 (48.95)	5.99 (34.95)	5.68 (31.28)	6.19 (37.33)	6.79 (45.03)	6.57 (42.20)	6.04 (35.47)	5.88 (33.53)
SEm±	0.07	0.10	0.07	0.08	0.26	0.05	0.05	0.03	0.05	0.06
CD (p=0.05)	0.19	0.28	0.21	0.23	0.77	0.14	0.14	0.09	0.15	0.16

Table 2: Effect of weed control treatments on weed density (No. m^{-2}) of *Anagallis arvensis* and miscellaneous weeds

Treatment	*Anagallis arvensis* (No. m^{-2})					Miscellaneous weeds (No. m^{-2})				
	30 DAS	60 DAS	90 DAS	120 DAS	Maturity	30 DAS	60 DAS	90 DAS	120 DAS	Maturity
T_1	3.69 (12.63)	4.92 (23.17)	4.15 (16.20)	3.67 (12.50)	3.29 (9.81)	3.38 (10.40)	4.04 (15.33)	3.92 (14.37)	3.37 (10.37)	3.11 (8.68)
T_2	4.52 (19.47)	5.75 (32.03)	4.79 (21.90)	4.58 (19.97)	4.30 (17.51)	3.92 (14.33)	4.64 (20.57)	4.52 (19.47)	4.07 (15.53)	3.82 (13.61)
T_3	4.42 (18.53)	5.72 (31.68)	4.76 (21.63)	4.27 (17.23)	3.98 (14.81)	3.65 (12.32)	4.45 (18.80)	4.41 (18.43)	3.92 (14.37)	3.69 (12.62)
T_4	2.94 (7.67)	3.58 (11.83)	3.40 (10.53)	2.95 (7.68)	2.48 (5.16)	2.87 (7.27)	3.50 (11.23)	3.41 (10.60)	3.04 (8.23)	2.75 (6.56)
T_5	3.68 (12.57)	4.88 (22.83)	4.19 (16.53)	3.63 (12.17)	3.27 (9.72)	3.36 (10.27)	4.04 (15.33)	3.92 (14.33)	3.38 (10.43)	3.12 (8.73)
T_6	4.50 (19.27)	5.79 (32.47)	4.77 (21.73)	4.50 (19.27)	4.23 (16.89)	3.92 (14.33)	4.62 (20.33)	4.51 (19.33)	4.07 (15.60)	3.87 (13.97)
T_7	4.38 (18.20)	5.73 (31.87)	4.76 (21.62)	4.25 (17.07)	3.95 (14.57)	3.65 (12.33)	4.40 (18.40)	4.35 (17.93)	3.89 (14.17)	3.68 (12.54)
T_8	2.98 (7.93)	3.59 (11.87)	3.28 (9.77)	2.85 (7.10)	2.41 (4.81)	2.89 (7.37)	3.51 (11.31)	3.34 (10.13)	3.01 (8.03)	2.74 (6.51)
T_9	6.56 (42.03)	5.47 (28.90)	4.35 (17.93)	3.90 (14.27)	3.58 (11.88)	6.64 (43.07)	4.35 (17.93)	4.17 (16.37)	3.66 (12.40)	3.43 (10.78)
T_{10}	6.62 (42.77)	5.40 (28.33)	4.35 (17.90)	3.91 (14.27)	3.58 (11.85)	6.68 (43.67)	4.34 (17.87)	4.17 (16.40)	3.68 (12.57)	3.48 (11.10)
T_{11}	1.00 (0.00)	1.72 (1.97)	2.26 (4.10)	2.34 (4.50)	1.78 (2.20)	1.00 (0.00)	1.97 (2.88)	1.44 (1.07)	1.29 (0.70)	1.25 (0.55)
T_{12}	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_{13}	6.78 (44.93)	7.57 (56.23)	6.93 (47.03)	6.79 (45.13)	6.62 (42.79)	6.95 (47.33)	7.72 (58.60)	7.30 (52.23)	6.73 (44.23)	6.68 (43.59)
SEm±	0.05	0.09	0.03	0.06	0.06	0.03	0.03	0.02	0.05	0.04
CD (p=0.05)	0.15	0.26	0.10	0.17	0.18	0.09	0.09	0.06	0.14	0.11

Table 3: Effect of weed control treatments on yield attributes of chickpea

Treatments	Pods/plant	Seeds/pod	Branches/plant	100 seed weight (g)	Biological yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
T_1	37.72	1.60	7.87	14.50	4368	1702	2666	39.0
T_2	34.37	1.33	6.97	14.48	3353	1309	2043	39.0
T_3	35.63	1.39	7.40	14.47	3697	1385	2312	37.5
T_4	39.82	1.72	8.23	14.66	4594	1811	2782	39.4
T_5	38.27	1.61	7.90	14.66	4424	1784	2640	40.3
T_6	34.45	1.30	7.10	14.52	3365	1323	2061	38.7
T_7	36.50	1.35	7.57	14.43	3799	1475	2324	38.8
T_8	40.48	1.73	8.87	14.41	4707	1827	2880	38.8
T_9	22.07	1.23	5.20	14.57	2035	767	1268	37.7
T_{10}	21.73	1.27	5.17	14.54	1982	755	1227	38.3
T_{11}	42.20	1.85	8.93	14.65	4913	1940	2973	39.5
T_{12}	42.97	1.86	8.87	14.65	4957	1968	2989	39.7
T_{13}	26.77	1.13	4.50	14.45	2376	880	1497	36.9
SEm±	0.67	0.05	0.26	0.08	45	37	36	1.0
CD (p=0.05)	1.96	0.15	0.76	NS	133	110	106	NS

Conclusion

This paper presents an evaluation of the effectiveness of pre-plant incorporated (PPI), pre-emergence (PRE) and post-emergence (PoE) herbicides, examining their impact on weed density, yield attributes and yield. The paper is centered on the effects of treatments on various characteristics that ultimately determine yield. The results obtained and detailed in the upcoming pages aim to lead to a valid conclusion. The results of this study showed that PPI and PRE application of any herbicide did not cause any phytotoxic effect on chickpea. The Ready mix (RM) herbicide applied as PPI and PRE performed better than sole PPI, PRE, and POE herbicides. Among herbicidal treatments, PPI and PRE application of pendimethalin + imazethapyr (RM) @ 1000 g a.i ha^{-1} gave excellent control of complex weed flora and increased the yield of chickpea significantly over the weedy check. Unchecked growth of weeds in weedy check caused 55.2% reduction in seed yield as compared to weed free treatment. Maximum seed yield (1968 kg ha^{-1}) and higher value of yield attributes of chickpea were recorded with weed free treatment which were statistically at par with two hand hoeing performed at 30 and 50 DAS (1940 kg ha^{-1}) and among herbicidal treatments, maximum seed yield was recorded with PRE application of pendimethalin + imazethapyr (RM) at 1000 g ha^{-1} (1827 kg ha^{-1}).

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